SPECIAL REPORT: WHAT'S A SCUD?

AIR&SPACE

Smithsonian

MAY 2003

HUGHES RACER II

JIM WRIGHT'S SPECTACULAR H-1 REPLICA

PLAN-AHEAD GUIDE: HOW TO DO OSHKOSH

PAGE 28

Smithsonian
National Air and Space Museum

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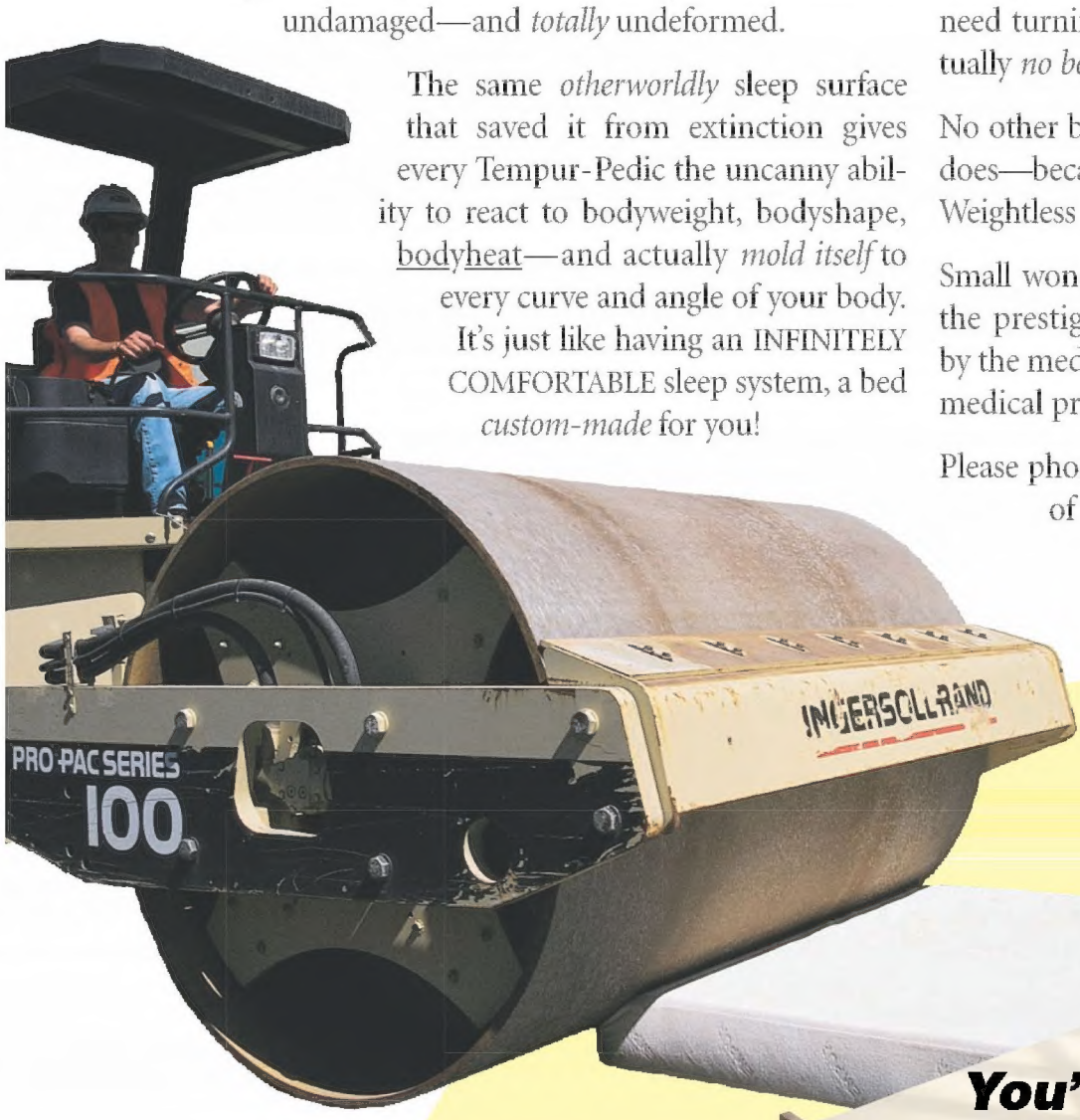

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Pioneers

Four of them—Dave Brown, Laurel Clark, Willie McCool, and Ilan Ramon—were returning from their first trip into space. The others—Mike Anderson, Kalpana Chawla, and Rick Husband—had flown only once before. They were all at an early stage in their careers as astronauts, and the exhilaration and heightened perspective of space travel were still relatively new to them.

We can suppose that the astronauts' final moments before *Columbia*'s failed reentry on February 1 were happy ones. In the last hour after leaving orbit, they would have been enjoying the elation that follows a job well done, already starting to play back memories of a mind-expanding experience only a few hundred humans have ever known. It's hardly consolation, but it's a nice image nonetheless.

Now, along with the outpouring of grief, come the inevitable questions. Should the space shuttle be phased out? That's easy—of course it should. Hardly anyone flies DC-3s anymore, because we've moved on to something better. NASA was already making plans for new orbital vehicles before the accident, and the agency should continue.

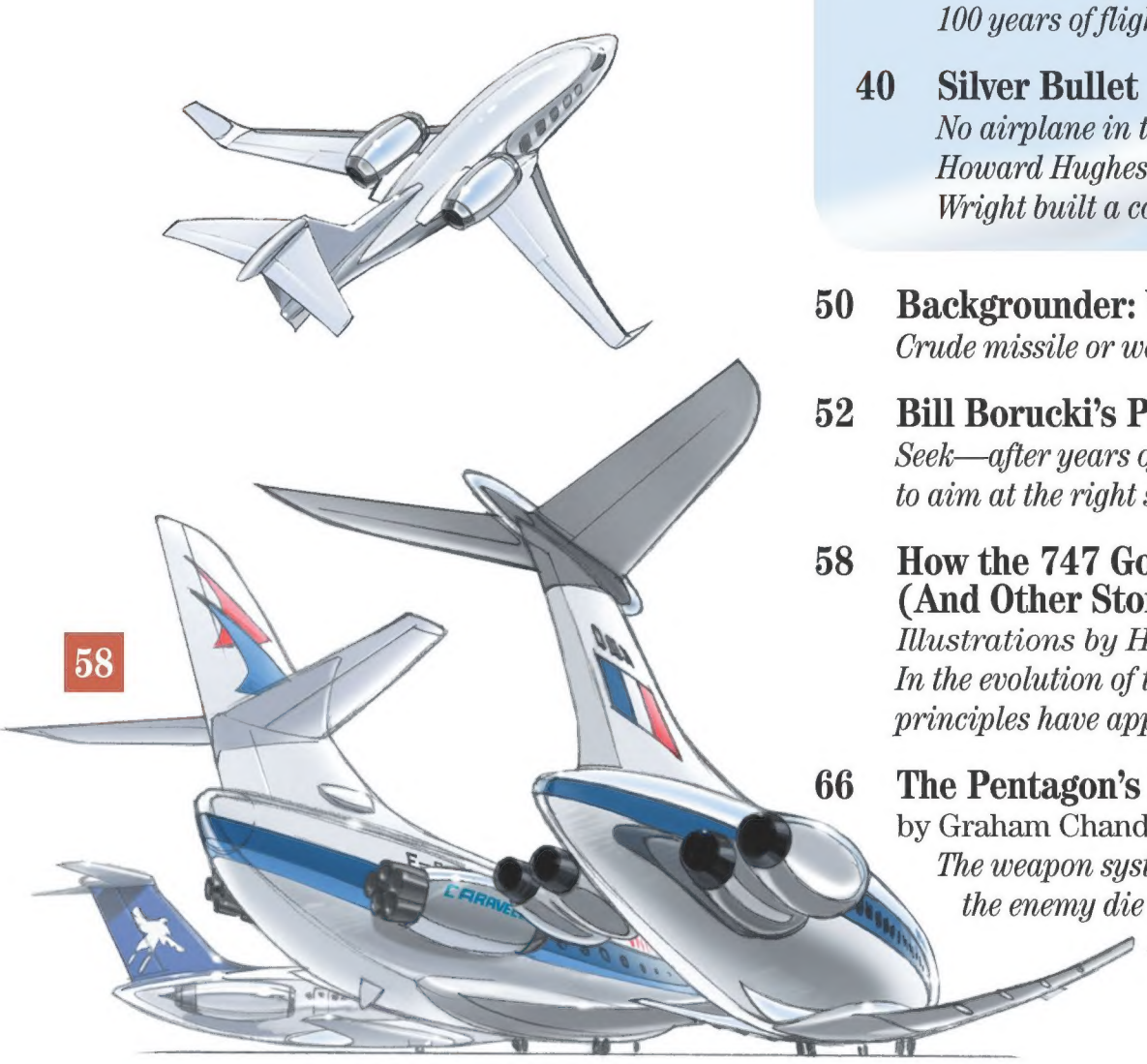
More fundamental is the question of whether we should keep sending astronauts into space. Rocketing people into orbit entails exorbitant cost and great risk, and for all our effort, we haven't traveled very far. If the universe is an ocean, we're still tethered to the dock. Even the Apollo astronauts never reached the first breakers—the moon is a mere 250,000 miles away, less than one percent of the distance to Mars. Alpha Centauri, the closest star to our sun, is 100 million times farther. The crew of STS-107 were pioneers in a journey that will last centuries, and that will have many more setbacks. All we can promise here at the beginning is to keep going as fast as our technology, economics, and politics allow.

What is it about space exploration that brings out the philosopher in us? After her first shuttle flight in 1997, Kalpana Chawla, the India-born engineer, pilot, and astronaut who was on *Columbia*'s final voyage, sent this magazine an essay she'd written shortly after her return, "Ninety Minutes," a meditation on viewing one complete orbit of Earth from space. We're reprinting it on page 18. While charming and personal, Chawla's essay also evokes a sense of the mysterious. She was keenly tuned to this deeper meaning of spaceflight, and had the ability to express what many astronauts undoubtedly feel. Her crewmates, if we'd had the chance to ask them, would likely have said, *Yes, that's it.*

—The editors

KENNEDY SPACE CENTER

Dawn at launch pad 39A, Kennedy Space Center, Florida.



AIR&SPACE

Smithsonian

April/May 2003 ✳ Volume 18 • Number 1

FEATURES

Special Section: Airshows 2003

Cover:
You might call Chad Slattery's masterful composition starring Jim Wright's new replica of the Hughes H-1 Racer a reflection on perfection.

DEPARTMENTS

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Bibliophilia

The library of the National Air and Space Museum is a true gem. One of the premier collections of its type, the library is one of 22 branches of the Smithsonian Institution Libraries, which is similar to a university library system. It supports the specialized research of the Museum's staff as well as that of researchers from around the world.

The general collection of the library is made up of monographs, serials, technical reports, government publications, and microforms. The content of the approximately 40,000 bound volumes in the collection reflects the variety of interests at the Museum. The great majority of the collection focuses on or is directly related to aerospace subjects, including history, air transport, ballooning, propulsion, military aviation, and astronomy, along with spacecraft instrumentation and design, rocket engine design, lunar, planetary, and terrestrial geology, and remote sensing.

In the beginning, the collection consisted largely of the Institute of Aeronautical Sciences' gift of portions of their library. In 1972, the collection was organized into a library by combining the Museum's historical materials, books collected by curators, and the Institute of Aeronautics' gift, and was located in the Smithsonian's Arts and Industries building. An intensive effort to supplement this rich historical collection with current materials followed. One major donation was NASA's contribution of the Bellcomm Library on space sciences and exploration. In addition, the Federal Aviation Administration has repeatedly donated extensive agency holdings on civil aviation. Collections from several locations were merged prior to the opening of the new Museum in 1976.

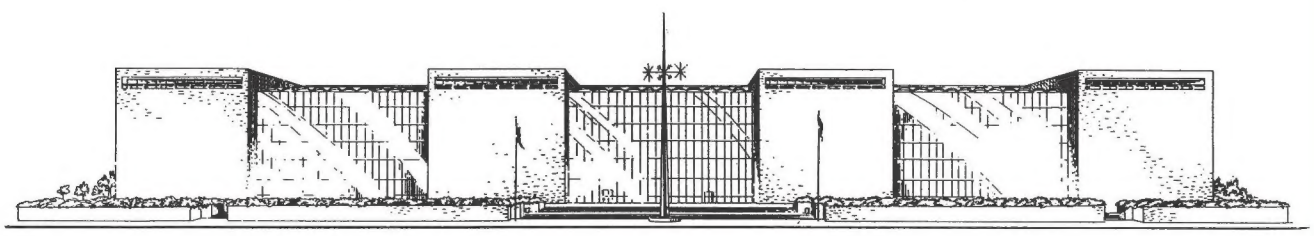
The library has a number of unusual resources: The Bella Landauer Collection of Sheet Music contains approximately 1,100 pieces with over 870 titles chronicling aviation history and its sense of adventure and romance.

The library also has a collection of over 200 sound recordings that are international in scope and wide-ranging in content. Here are recordings of President Calvin Coolidge and Charles Lindbergh at the welcoming ceremony after Lindbergh's historic 1927 transatlantic flight; of Frank Borman narrating "The Sounds of the Space Age"; and for children, a rendition of the "Space Alphabet." The recordings truly complement other resources in the collection.

Perhaps the most valuable part of the library is the DeWitt Clinton Ramsey Room, which houses our rarest treasures. For instance, the room contains William A. M. Burden's collection of early ballooning works and important first editions, many of the latter autographed by the pioneers of flight. The collection also has early works on flight by Samuel P. Langley and the Wright brothers as well as on the rocketry of Robert Goddard.

The resources of the library are a telephone call (202-633-2320) or an e-mail (*libmail@si.edu*) away. For more information, please visit our Web site: *www.sil.si.edu/libraries/museum-hp.htm*

—J.R. Dailey is the director of the National Air and Space Museum.



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LETTERS

Aviation Comes Alive

Amid the competition over who can build (and fly) the most accurate, authentic replica of a Wright aeroplane ("In Search of the Real Wright *Flyer*," Dec. 2002/Jan. 2003), I was brought gently down to earth by the touching personal observations of Tom Crouch ("Meeting Wilbur and Orville," Feb./Mar. 2003).

For *my* money, a historian who relates a deep emotional connection to a person in the past is worth his weight in a stack of aviation statistics.

Giacinta Bradley Koontz
Durango, Colorado

Don't Forget the Gliders

I have a low-cost alternative for readers interested in celebrating the invention of the airplane ("100 Ways to Celebrate 100 Years of Flight," Feb./Mar. 2003). On October 8, 2003, the Crawford Auto-Aviation Museum of the Western Reserve Historical Society in Cleveland will take its replica of the Wright brothers' 1902 glider to Kitty Hawk, North Carolina, for a series of re-created flights. (It will be the second such series; the first was made last year.)

We invite your readers to join us, and not just as observers. Those interested in joining our ground crew should contact me directly.

Edward Jay Pershey
Director of Education and Research
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Custer's Continuing Stand

As the son of Willard Custer, I grew up with the Channel Wing ("Wrong Turns," Feb./Mar. 2003), helping Dad build and fly every size model and airfoil. We built four full-size aircraft, and I flew the last three, accumulating around 5,000 hours. This aircraft handled beautifully and could be flown by any multi-engine pilot. Compared to the V-22 Osprey, it carries more, flies farther and faster, needs less maintenance and fuel, and has a far smaller initial cost. Check out our Web site, *www.custerchannelwing.com*, and judge for yourself.

Harold R. Custer
Vero Beach, Florida

It's Not Much, But It's Home

The description of a farmer buying a Waco glider just for the box ("A Waco's Happy Ending," Aug./Sept. 2002) reminded me of a story I heard from a veteran of a World War II glider unit. At the war's end, he watched the sale of new, surplus gliders. Each was purchased for well under $100. Most of the purchasers immediately opened the sturdy shipping case, pulled out the glider and discarded it, and took the shipping box home—to live in. Housing was extremely scarce at that time.

C. Brooks Henderson
Dunnellon, Florida

Depressing Question

Reading about live-fire survivability testing of military aircraft ("Shoot 'Em Up," Oct./Nov. 2002) made me wonder: Is similar testing now needed to improve the survivability of commercial passenger jets attacked by terrorists with, for example, shoulder-fired surface-to-air missiles?

Tom McAbee
Lexington, South Carolina

Make That a Double

The picture of Chuck Yeager in "10 Great Pilots" (Feb./Mar. 2003) shows the pilot climbing out of what at first appears to be a P-51, but I wonder. The fuselage is deeper than a -51's, especially in front of the wing. See how small Yeager appears in relation to the airplane? The best clue is the location of the landing gear: It comes out of the wing root, whereas the gear on the -51 was way out on the wing. So is the airplane a Twin Mustang?

Ted R. Smith
Hot Springs Village, Arizona

Editors' reply: We believe it is.

Be Careful Out There

When I received the Feb./Mar. 2003, I began reading it just before retiring for the night. The first thing that caught my eye was the photograph on the cover, showing a fellow pulling out the DC-3's wheel chocks, propellers whirling just a few feet from his head. *Whoa*, I thought, *that's a good way to get your block knocked off.* I wondered how many times that gruesome accident had actually

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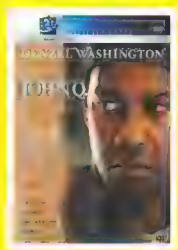

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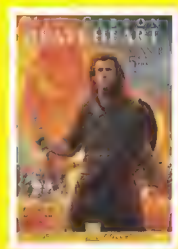

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happened over the last 100 years. Then I turned out the light and went to sleep.

Imagine my shock when I woke the next morning to hear on the news that just after I'd turned in the night before, a 23-year-old man had been killed by a twin-engine turboprop propeller at Cleveland's Burke Lakefront Airport.

Yes, my friends, it still happens today.

Keith Kunde
Independence, Ohio

Buran Booster

I object to the title "White Elephant" for the article on the Soviets' Buran (Dec. 2002/Jan. 2003). The Energia-Buran combination cost no more than the Soviet N-1 moonship, and the development of that craft in the 1960s and 1970s did not bankrupt the U.S.S.R.

I also disagree with the caption on page 35 that calls the Energia twin boosters "total throwaways." They had compartments for parachutes, to eventually permit recovery and reuse. These liquid-fuel boosters were also safer than the solid rocket boosters that caused the *Challenger* disaster.

In *Columbia*-style orbiters, the three space shuttle main engines become dead weight on orbit when the external tank is staged. The SSMEs are also complicated and more costly to return than they are worth. Because they are so large, the orbiter has less room for fuel, so NASA has to use high-density on-orbit-maneuver propellants, which are a hazardous-material nightmare. In the Russian design, simpler, single-use hydrogen engines under the external tank—the Energia itself—allowed the Buran to carry sintin (synthetic kerosene), which is a safer fuel, and for an oxidant it could use oxygen, which in an emergency would be safer to breathe than the *Columbia*'s nitrogen tetroxide. Also, having these engines enabled the Soviet vehicle to take five times what our orbiters can carry. Our orbiters must carry loads internally, after booster separation. With Energia, the 80-ton Buran with its 20-ton cargo could be replaced by a 100-ton payload pod. Divided into four 100-ton modules, the International Space Station could have been assembled in just four or five Energia flights.

Jeff Wright
Pinson, Alabama

Mr. Jones and His Many Wings

In "Defining Moments" (Feb./Mar. 2003), "A Man Named Jones" is identified as Richard, but he is actually Robert T. Jones, or R.T., as we at the NACA's Ames center in California called him.

In addition to studying conventional swept wings, R.T. later worked hard to convince the aeronautics community of the even greater aerodynamic efficiencies afforded by a flying "oblique," or yawed, wing. Researchers at NASA's Dryden center successfully tested the oblique wing on a sub-scale airplane in flight. Ames and Boeing also conducted studies of an all-wing supersonic transport. The transport was envisioned to take off with little or no wing sweep, and as Mach number increased, the sweep angle would gradually increase so as to always be at the optimum value. Practical issues, such as public acceptance for commercial use and integration with ground handling facilities at major passenger airports, eventually ended the studies.

Victor L. Peterson
Deputy Director (ret.)
NASA Ames Research Center
Los Altos, California

Corrections

Feb./Mar. 2003 "10 Great Pilots": James Doolittle's raid included 16, not 15, B-25s, and Doolittle was awarded the Medal of Honor, not the Congressional Medal of Honor. Charles Lindbergh shot down a Ki-51 Sonia, not a Zero.

"10 Great Flights": The second mid-air refueling, not the first, covered 3,293 miles (duration: 37 hours, 25 minutes). Chuck Yeager broke the sound barrier on October 14, not 16, 1947. The photograph in "First armed air-to-air kill" shows a Blériot, not a Voisin. (A Blériot was the first airplane used in war, but it was used for reconnaissance, not combat.)

Timeline, 1934: The Schneider Cup no longer existed when Francesco Agello set his speed record.

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"All these aircraft set every milestone in aerospace history..."

PHOTO: ERIC LONG

"Thirty-one years in the Air Force gave me many great opportunities. I flew several memorable Aircraft including the F-100, the F-105, and even a MiG-17 when I was stationed in China as Defense Attaché."

JON REYNOLDS

Jon Reynolds, Brigadier General, USAF (Ret.) in front of one of his favorite planes in the Smithsonian collection, the F-100D Super Sabre. The aircraft is presently kept at the Paul E. Garber Preservation, Restoration, and Storage Facility in Suitland, Maryland.

His first opportunity was at age 12, when Jon Reynolds flew in a float plane off a lake in Canada. Hooked on flying, he went on to an extraordinary career. He's a pilot with two combat tours in Vietnam, a retired Air Force Brigadier General, a professor with a Ph.D. in history who taught at the Air Force Academy, and a Board member of the National Air and Space Museum.

Jon Reynolds and his wife, Emilee, have also taken the opportunity to make the National Air and Space Museum beneficiary of a generous trust. They are now members of the *Smithsonian Legacy Society*.

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A&S 5-03

The Second Time Around

Ed Shadle, who hopes to break the land speed record—and the sound barrier—next year, didn't have enough money to hire a team of engineers. Fortunately, he didn't have to. "Kelly Johnson did most of the work for us," he explains.

Shadle and partner Keith Zanghi are developing a wingless, four-wheel version of legendary designer Kelly Johnson's fabled Mach 2 interceptor, the Lockheed F-104 Starfighter. And not just any Starfighter. Their North American Eagle was fashioned out of an F-104A that saw extensive action during the 1950s and '60s at Edwards Air Force Base in California.

In its previous incarnation, the land racer was a chase plane in programs ranging from the X-2 to the X-15, and it was flown by such test pilots as Scott Crossfield, Joe Walker, Bill Dana, Pete Knight, and Joe Engle. Shadle says it was in line to become the fourth NF-104A to be fitted with a supplementary rocket engine and reaction control jets, but the aerospace training program in which such aircraft served was canceled in 1963 after Chuck Yeager lost control at 104,000 feet and ejected with his helmet on fire—an incident immortalized in the final scenes of the film *The Right Stuff*.

Shadle, a veteran racer who has gone faster than 300 mph, originally hooked up with Zanghi, a drag-racer-turned-Boeing-manager, on another jet car. Although that project flamed out, they remained determined to break the current land speed record—763.035 mph, set by Royal Air Force fighter pilot Andy Green in 1997 at Black Rock Desert, Nevada.

Zanghi had an epiphany while visiting the National Air and Space Museum, where he spent 30 minutes gazing at an F-104. The dart-like Starfighter is essentially a fuselage wrapped around a General Electric J79 engine. Better still, the J79 had been proven in the epic battles at Utah's Bonneville Salt Flats between Craig Breedlove and Art Arfons, who exchanged the land speed record five times in 1964 and 1965 while raising the mark from 434.22 mph to 600.601 mph.

Unfortunately, by the time Zanghi and Shadle got around to shopping for F-104s, there were none left at the Davis Monthan Air Force Base storage facility in Arizona. When they did get a line on a Starfighter, another buyer beat them to it. Finally, in 1998, they found an F-104A in Maine that had been sold as surplus in 1971, and they paid $35,000 for the decrepit hulk. "It was about six months from being turned into beer cans," Zanghi says. A small cadre of volunteers repaired the fuselage and fabricated front and rear suspensions.

The team's biggest challenge—besides raising money—may be keeping its Eagle from flying. The airplane-car will be pinned to the ground by two pairs of tiny canards angled to create down force rather than lift. But with an anticipated 20,000 pounds of thrust from a modified F-4-spec J79-15, Shadle figures he should hit 835 mph in 3.7 miles on wheels specially fabricated out of solid aluminum billet (conventional tires would shred at that speed). "I'm amazed that nobody thought of this before," he says.

—Preston Lerner

NORTH AMERICAN EAGLE (3)

An F-104A in its salad days (top); a shadow of its former self (above); and prepped for a run on the land speed record and a new career (center).

Channeling Blériot

Daedalus was dead right about his son, Icarus. Despite his dad's warning, Icarus flapped himself higher and higher until the sun melted his wax wings, and he returned to Earth fatally faster than he had planned. The Greek myth is more about excess pride than the principles of flight, but on June 21, Felix Baumgartner will test both limits. The 34-year-old from Salzburg, Austria, thinks Icarus suffered from bad materials and bad marketing.

Baumgartner's Icarus Two project is $4.5 million and more than 25 glide tests toward completion. His six-foot delta wing of fine carbon fiber, backed by engineers at the Austrian company Carbotech, a sponsor, and a knockout Web site (*www.felixbaumgartner.com*), may carry him in a slippery red suit across the English Channel.

Baumgartner had first put his faith in wings produced by two aerodynamics students in Munich, whose design proved to be more anvil than airfoil; its glide ratio was 1:3, meaning it would lose a mile in altitude for every three miles of forward flight. Baumgartner turned to Rudiger Kunz, a renowned glider maker and former manager of design for the Eurofighter. Kunz stepped out of retirement to work with Carbotech, which makes high-performance auto racing components. Carbotech built autoclaves to form its XC-KL wing at 392 degrees Fahrenheit and pressures of up to 144.93 pounds per square inch.

The new design had a glide ratio of 1:6. With kind winds and the pilot's finesse, the airfoil could carry Baumgartner the 21 miles that connect Dover to Calais after he exits an aircraft or a balloon at 29,000 feet. He expects to reach 300 mph before stabilizing to glide at 155 mph, completing the hop in 10 minutes and making the last of his descent with a parachute.

Baumgartner built his fame leaping from buildings, antennas, structures, and Earth—B.A.S.E jumping. B.A.S.E'rs hold their ripcords until the last possible second, dropping flat out for the ground; enough have died to result in the sport being banned in most countries. Baumgartner has flung himself from the Cristo Redentor statue in Rio de Janeiro, Brazil, and two years later from the Finger of God, a 5,444-foot mountain 50 miles inland. He's also skipped the elevator at the 1,483-foot Petronas Twin Towers in Kuala Lumpur, Malaysia.

Last November, Baumgartner was strapped on the roof of his Porsche 911 and sent flying down the Salzburg Airport runway to test his pointy helmet and oxygen tank. Further runs are planned for this spring at the Lausitzring test track in Germany.

FELIX BAUMGARTNER

Felix Baumgartner and wing make test runs atop a Porsche.

"It is like driving a Formula One car," he told a mosh pit of media. "The equipment is extremely sensitive and quite delicate, which means that any problem is a big one." Baumgartner notes that it has been 94 years since Louis Blériot made the first aerial crossing of the English Channel, and says, "I want to show people we don't need a plane anymore. I'm my own plane."

—Roger A. Mola

The Pride of Newark

When the Port Authority of New York and New Jersey lengthened Newark Liberty International Runway 31R right up to the staircase of an old storage building, the workers' first reaction might well have been to call for a wrecking ball—five minutes, problem solved. But the two-story Art Deco structure was Newark's first terminal—it was christened by Amelia Earhart in 1935—and it was protected under the Landmarks Preservation Act.

"This was a very important building in the history of aviation," says Richard Southwick, a restoration architect for the New York firm Beyer Blinder Belle. "For the first time, the plane could actually taxi up to the building and then

They Hear Voices

Charles Gardner's voice often trills with delight, as if he were summarizing the first act of a comic opera. Instead, he's reporting for the British Broadcasting Company, in July 1940, from the cliffs of Dover. "There are about one, two, three, four, five, six…ten German machines dive-bombing the convoy, which is just out to sea in the Channel…. Now the British fighters are coming up…guns going like anything!"

Gardner describes the veering, wheeling, and chasing: "There's a Spitfire dropping in behind the first two [Messerschmitts]—he'll get them! The RAF fighters have really got these boys taped…. I wouldn't like to be in that first Messerschmitt."

These sounds of the Battle of Britain are as close as your computer's mouse. The three partners who manage Lost and Found Aviation Sounds (LAFAS) are establishing an archive of audio recordings relating to aviation and spaceflight. Anyone can listen to samples on the group's Web site, *www.one-voice.co.uk/lafas*.

"We're not out to profit from this venture," Chris Butterfield, LAFAS curator, says from his studio in Lincolnshire, England. "Our sole aim is to preserve aviation history and memories before they are lost forever."

The effort to build the archive began when a friend of Butterfield's discovered four hours of tapes featuring Chuck Yeager, his boss Al Boyd, and others involved in breaking the sound barrier at California's Muroc Air Force Base in 1947. Boyd is heard explaining why Yeager was their man when the roster of 125 test pilots included some 25 jocks qualified for supersonic flight. "We'd hoped to find a pilot that didn't have a family or who wasn't married presently," Boyd says. "After interviewing all of the pilots, we always came back to Yeager." One of history's small ironies is that the XS-1 took the name *Glamorous Glennis*, after Yeager's wife.

After this major Muroc find, Butterfield chanced upon the tape of Gardner's live account, which required extensive (and tricky) restoration. At present, LAFAS consists of little more than the Web site and three people with technical know-how and willing hands. Besides the donation of other recordings, financial support is sought. Butterfield, however, disdains the practice of "going cap in hand to charitable foundations," as he describes it. "Self-financing through CD sales and consultancy work for museums look to be the way forward for us."

—Ronald Ahrens

passengers could walk up to the plane instead of across the tarmac."

The building was shaped like a pair of wings with glass tips; you could stand outside one wingtip and see through to the other. It had the world's first control tower, six waiting rooms, baggage handling facilities, and a restaurant. Built of buff-colored and beige brick with marble decorative columns and aluminum eagles in flight, the terminal also featured a terrazzo eagle in the center of its terrazzo floor, with its wings spread wide.

In order to preserve the building, the architects decided to move it. But with its 70-year-old facade measuring 200 feet long, it was the largest building anyone ever attempted moving. Southwick's team chopped the terminal in three parts, raised them on sophisticated dollies, moved them three-quarters of a mile to a new foundation, and reassembled the terminal just as it was—with nary a crack in the structure. "It was like lifting a 55,000-ton egg," Southwick says.

One airport historian believes the move violated the building's aesthetic integrity. "It's fabulous that the facility is still there," says Geoffrey Arend, author of numerous books on historical airports. "It's sort of a living thing that people can see, as opposed to walking into the museum, a great cathedral of architecture and art." But, he adds, the architects placed the terminal in its original orientation instead of turned 180 degrees, as a passenger would have seen it deplaning from a DC-3. "The most important part of the artifact is facing an empty courtyard," he says. And then there's the stylish period plaque dedicated to Wiley Post and Will Rogers.

NASM (SI NEG. #77-4191)

An American Airlines DC-3 genuflects to the Newark terminal in 1937.

Instead of bolting it to the original spot near one of the stairways, the preservationists put it over the entrance to a bathroom. "You can still see where they filled in the holes" in the original location, Arend says.

Still, Arend is delighted the building was saved. "It could have been knocked down, and instead a lot of people did a good job saving it," he says. "The place is beautiful and we're lucky to have it."

—Phil Scott

Light That Candle!

In their quest for the perfect solid rocket fuel, aerospace engineers have tried just about everything—polyethylene, mothballs, asphalt—anything containing energy-rich hydrocarbons that might burn in the presence of oxygen. Early in the space program, rocket specialists looked into using garbage produced on board a spacecraft as propellant, says Brian Cantwell, an aerospace engineering professor at Stanford University in California. "And at one point, as a joke, somebody used a salami," he says.

But when Cantwell's then-graduate student Arif Karabeyoglu came up to him triumphantly after finding what may be the best solid rocket fuel yet, even Cantwell was surprised. "My first response was: *Wax*?" he recalls. Yes, wax. Or more precisely, paraffin, the stuff of crayons and candles, and more specific yet, hurricane candles.

Rocket scientists have been trying for decades to build hybrid rockets that combine the best features of solid- and liquid-fueled vehicles. Solid rockets, like those used on the space shuttle, have high thrust, and are simple compared to liquid engines, which need high-pressure turbopumps. But because their fuel and oxidizer are mixed together, solids are dangerous to store and work with. And they can't be throttled in flight—once lit, they keep burning until the fuel is exhausted. Hybrids separate the liquid oxidizer from the solid fuel, so the flow of oxidizer (and therefore the thrust) can be controlled or even shut down and started up again.

The trouble is, engineers have had difficulty getting the solid fuel in a hybrid to burn fast enough. In the mid-1990s, Cantwell and his co-workers noted the results of Air Force experiments in which certain supercooled fuels

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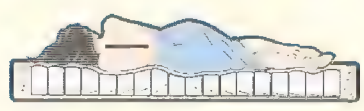

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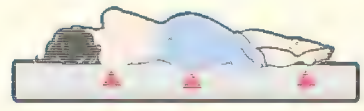

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appeared to burn longer. On closer examination, they found the reason: A microscopic layer of turbulence in the melted liquid at the material's surface helped prolong combustion. Low-viscosity materials worked best. So Karabeyoglu went hunting for a fuel with the right combination of physical properties, and *voilà*: paraffin.

With funding and participation from engineers at NASA's Ames Research Center in California, the Stanford team has been building rockets of steadily increasing size, and this spring plans to launch a 12-foot version to 80,000 feet, about as high as the government allows without regulatory approval. Cantwell's group wants to eventually build a sounding rocket for suborbital launches, then a full-size vehicle. Another member of the team, David Altman, has founded a startup in nearby Menlo Park, called Space Propulsion Group, Inc., to develop the technology. A replacement for the shuttle's boosters is still "many years away," however, according to Cantwell.

The paraffin hybrid appears to be one of those inventions with few, if any, down sides. The wax has about the same efficiency as kerosene, a standard rocket fuel. Conventional solid rockets produce perchlorate, an environmental pollutant, but the wax rocket produces harmless carbon dioxide and water.

The paraffin fuel should also be easy—and therefore cheap—to store and handle safely. "You could literally fabricate this system at the launch site," says Cantwell. He believes that by using additives like aluminum in the paraffin fuel and making other adjustments, it may even be possible to replace super-cooled liquid oxygen with easily storable hydrogen peroxide as the rocket's oxidizer.

The idea has generated excitement among rocket experts, says Cantwell, although "there's a lot of temerity" about abandoning tried-and-true methods in a business that hasn't changed much since World War II. "It's not what I would call a fast-moving field," he jokes.

—Tony Reichhardt

The Invasion of Mars

Taking advantage of the closest approach between Earth and Mars in 17 years, NASA and the European Space Agency plan to dispatch a wave of robotic explorers to Mars this summer. "They are all complementary in their science goals," says NASA's Mars exploration program chief Orlando Figueroa.

NASA, for example, plans to launch twin rovers to scour two areas for geologic features, such as dry lakebeds. Four destinations have emerged as top contenders, three of which—Terra Meridiani, Gusev, and Isidis—have signs indicating the presence of water sometime in the planet's history. "These sites appear capable of addressing the objectives of the rover missions—to determine if water was present on Mars and whether there are conditions favorable to the preservation of evidence for ancient life," says Matthew Golombek, landing site scientist at NASA's Jet Propulsion Laboratory in Pasadena, California.

The European Space Agency's Mars Express is designed to make radar measurements from orbit to study the planet's atmosphere and look for signs of water. Mars Express, which will be Europe's first mission to Mars, also will carry a small rover designed to touch down on the planet's surface. Beagle 2, a relatively low-cost—about $50 million—lander built by the United Kingdom, is intended to hunt for water and organic matter on the planet's surface.

NASA's twin rovers are designed to cover as much ground in a day—about 100 yards—as the 1997 Mars Pathfinder rover did during its entire mission. "They carry sophisticated instruments that effectively make them robotic geologists," says mission manager Mark Adler.

The rovers' masts will carry remote sensing instruments, including high-resolution color cameras and infrared spectrometers for studying the minerals in rocks and soil. The rovers also will be equipped with a microscopic imager to see micron-size particles and textures, an alpha-particle/X-ray spectrometer to determine what elements the samples contain, and a Moessbauer spectrometer for determining the mineralogy of iron-bearing rocks. Each rover will carry a rock abrasion tool, similar to a geologist's rock hammer, to remove weathered surfaces from rocks and expose their interiors for analysis.

Already en route to the Red Planet is Japan's first Mars probe, Nozomi—"hope"—which will study the planet's upper atmosphere. Nozomi was launched in 1998 but was damaged by solar flares and put into a solar orbit until its frozen fuel could be thawed. Nozomi is on track to arrive at Mars next January.

NASA and Europe plan to launch their Mars probes in late May and June, with arrivals slated for seven months later. If successful, the spacecraft will be the first probes to touch down on the Martian surface since NASA's Mars Pathfinder mission. A lander mission was lost in 1998, along with an orbiter.

—Irene Brown

JPL

Easy, big fella! JPL technicians test the Mars Rover 2 suspension's range of motion on staggered ramps.

UPDATE

You Never Call Anymore

Pioneer 10, the planetary probe launched in 1972 on a two-year mission ("Fade to Black," June/July 2001), apparently sent its last signal to NASA's Jet Propulsion Laboratory in California on January 22. The spacecraft, which in 1983 became the first man-made object to leave the solar system, was 7.6 billion miles from Earth at the time. Scientists say it's likely that Pioneer 10's radioisotope thermoelectric generator has finally quit; no further attempts to make contact are planned.

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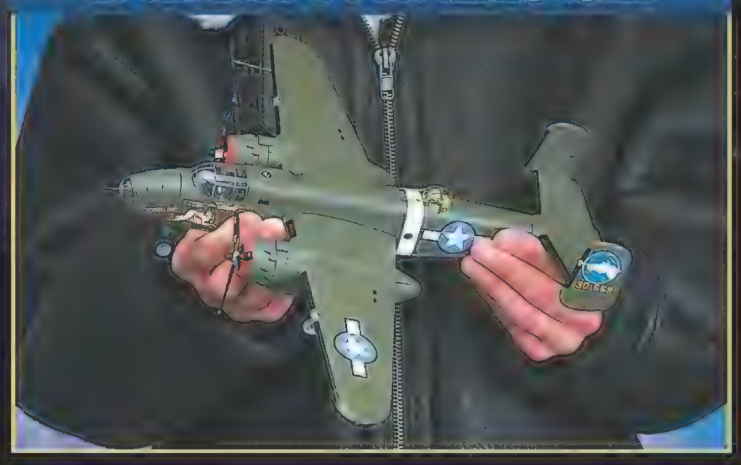

It first gained fame when it was selected for the daring Dolittle raid over Tokyo in 1942...a key battle that proved the Japanese homeland was vulnerable to bomber attack. And its place in military history was cemented when the Tondelayo, a twin-engine B-25 Mitchell Bomber, had an engine shot out during a raging 75 minute dogfight with 50 Japanese Zeroes... but survived to fight another day.

In addition to its value as a fighter plane, it was used for high and low-level bombing runs, strafing, photoreconnaissance, and submarine patrol. The B-25 was so popular, it was also flown by the British, Dutch, Australian, Chinese, and Russians. The B-25—and especially the famed Tondelayo—should be a part of your collection. *Mail the Order Form today!*

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The Good Old Days

The Paul E. Garber Preservation, Restoration and Storage Facility isn't much to look at. Built in 1952 on 21 acres in Suitland, Maryland, the 30 windowless buildings are plain as can be on the outside, and their interiors are dusty and poorly lit. But if you enter one of the pink metal prefabs and allow your eyes to adjust to the dimness, you'll see row upon row of hanging airplanes, like bats nesting in a cave. All told, the Garber facility houses more than 300 artifacts, from Aeroncas to Wacos.

Millions of people have visited the National Air and Space Museum in downtown Washington, D.C.—families with strollers, hand-holding couples, and tour groups from all over the world. But those in the know went to Garber, which over the years attracted a procession of overwhelmingly male airplane nuts. The faithful got their last chance to visit the facility on March 31; to begin the two-year transfer of artifacts to the Steven F. Udvar-Hazy Center, which opens on December 15, Garber ceased public tours, which had begun in 1977.

Named for Paul E. Garber, who collected more than 170 aircraft for the Smithsonian Institution during a career that began in 1920, Garber was more than just a place to store artifacts. The craftspeople who worked in Building 10 restored dozens of aircraft over the years. When Karl Heinzel saw the Garber facility on a local TV news program, he thought *That's the job I want.* Today he remembers the way the place was when he began working there in 1974. "It was like being on the frontier, but filled with airplanes," he says. The place was inhabited with swarms of hornets, the occasional wild dog, and plenty of snakes. There was also the smell of rotting whale bones, which wafted over from a nearby storage area that belonged to the National Museum of Natural History. "Most of the airplanes were in boxes outside," says Heinzel. "It was exciting to look into some box and discover some rare treasure that I had only read about."

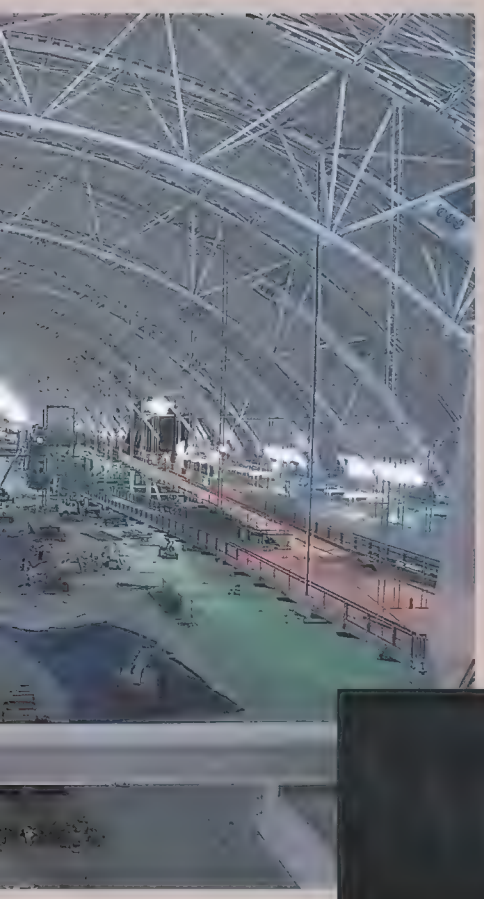
ERIC LONG

Last February, Garber restorer Matt Nazzaro tended to a Rocketdyne H-1 liquid-fuel engine, while Drew Mitchell (background) cleaned a Naval Aircraft Factory N3N-3.

NASM aeronautics curator Dorothy Cochrane also experienced the thrill of coming into contact with the history stored at Garber. She was in seventh grade during the Cuban missile crisis in 1962, and she remembers being scared when her teacher told the class, "The next few days will determine the fate of the world." Now Cochrane finds it hard to believe that she is the curator of the Hycon B camera, which—while carried aboard a U-2 reconnaissance airplane—recorded the images proving that Cuba had constructed missile sites.

During Garber's heyday, the 1980s and early 1990s, restoration technicians would undertake three or four major restorations at once, and job turnover among those who worked in Building 10 was so low that many started out as volunteers to prove their skills and increase their chances of landing a paid position. Their salaries would never make them rich, and during the summer they had to endure sweltering heat and humidity before an air conditioning system was installed in 1997, but most of them will tell you that working at Garber has been a dream job. "Getting paid to work around these aircraft reinforces the idea that I'll never have to grow up," jokes restorer Will Lee.

"Coming to work was an adventure," remembers restorer Bob McLean. "All



The Countdown Continues

With the December 15 opening of the National Air and Space Museum's Steven F. Udvar-Hazy Center just eight months away, work continues at the construction site, near Washington-Dulles International Airport in northern Virginia. Anchored by an airplane hangar more than 300 yards long, the Hazy Center will house some 300 air and space artifacts, including the Turner RT-14 Meteor (below), a racer designed by pilot Roscoe Turner in 1936. Turner first flew the RT-14 in competition at the 1937 National Air Race and ended up in third place. He returned to the Nationals the next year with the Meteor and finished first around the 30-lap course with a final lap speed of 283 mph. He won again in 1939, then retired from racing. For more information about the Steven F. Udvar-Hazy Center and the artifacts that will be displayed there, visit *www.nasm.edu*.

ERIC LONG (2)

around you, magnificent structures were being reborn. And the synergy was remarkable. Whatever problems you encountered, there always seemed to be someone in the small group of restorers that had at least part of the solution to the dilemma of the day." One day McLean needed to mold a piece of sheet metal into a wing leading edge, and he figured he'd need a big, complex piece of machinery, but now-retired technician Bob Padgett showed him how to do it by using two pieces of plywood and a vise as a makeshift press.

Though all of the Museum's curators have offices in downtown Washington, many of them looked for any excuse to go out to Garber. "Walking around at Garber made me feel like a kid again," says Dik Daso, curator of modern military aircraft. "I built models of almost every aircraft that is now a part of my curatorial collection. [Garber] is like my old bedroom, just a thousand times bigger, with real stuff." The artifacts that so enticed Daso range from amusing (a now-stuffed pet lion named Gilmore, which flew with racing pilot Roscoe Turner) to world-changing. Years before he was hired at the Museum, Daso visited Garber during the restoration of the *Enola Gay*, the Boeing B-29 that dropped an atomic bomb on Japan at the end of World War II. "To get so close to an icon like that was simply remarkable," he says. He also remembers the image of technician Scotty Wood hovering over the B-29's fuselage, polishing the silvery aluminum skin.

Over the years, Garber was visited by numerous pilots and aircraft designers, many of whom had personal connections to the artifacts on display. It was these visitors that most inspired the Garber staff. "They observed the fact that we were doing the best possible job we could to insure that the history they were part of is kept in perpetuity," says Karl Heinzel. Former aerobatic pilot Betty Skelton had won championships in 1949 and 1950 in a Pitts Special biplane, *Little Stinker*; when she saw it restored, she wept as she ran her hands over it.

As for himself, Heinzel says: "Someday I'll hang up my hammer and leave it to the next generation of airplane nuts to keep the preservation work going until all the old birds and the new birds that haven't flown yet have the safe haven they deserve." The restorers who succeed him will practice their art at a larger, glass-walled restoration shop to be built later at the Hazy Center. "A big, new, state-of-the-art shop will be nice," says Heinzel, "but it will be a long time before it ever starts to feel like an old pair of jeans—like Garber does."

—Diane Tedeschi

MUSEUM CALENDAR

April 10 "Mars in a New Light—The Latest Infrared and Visible Images from Mars Odyssey." Phil Christensen, principal investigator for the Mars Odyssey Thermal Emission Imaging System (THEMIS) instrument, will present the latest discoveries from the Red Planet. Tickets are required and may be obtained by calling (800) 529-2440 or visiting *www.tickets.com*. Einstein Planetarium, 7:30 p.m.

April 12 Family Day. Listen to the cosmic sounds of the Chromatics and talk to astronomy experts about choosing, using, and caring for telescopes and other astronomical instruments. Exploring the Universe Gallery (108), 10 a.m. to 3 p.m.

April 26 "Deep Impact and Amateur Astronomers." On July 4, 2005, the eighth NASA Discovery mission, Deep Impact, will excavate a crater on Comet 9P/Tempel 1. Join National Air and Space Museum lecturer Elizabeth Warner for a mission overview. Public telescopic observing follows, weather and time of sunset permitting. Einstein Planetarium, 6 p.m.

May 1 Space Day. As the nation prepares to commemorate the Centennial of Flight in December, Space Day 2003 will honor the past 100 years of aviation and space accomplishments while seeking to inspire the next generation of inventors, innovators, aviators, and dreamers. Space Day activities will be held throughout the National Air and Space Museum all day. For further information, visit *www.spaceday.org*.

May 7 "The 2003 Mars Exploration Rovers—Field Geologists on Mars." John Grant, geologist at the National Air and Space Museum's Center for Earth and Planetary Studies, will discuss the Mars 2003 rover mission and its science goals. Tickets are required and may be obtained by calling (800) 529-2440 or visiting *www.tickets.com*. Einstein Planetarium, 7:30 p.m.

Except where noted, no tickets or reservations are required. To find out more, visit www.nasm.edu *or call the Smithsonian Information line at (202) 357-2700; TTY (202) 357-1729.*

Ninety Minutes

Kalpana Chawla was one of seven astronauts who died February 1 when the space shuttle Columbia *broke apart on reentry. She wrote this reflection, which originally appeared in the Oct./Nov. 1999 issue, after returning from her 1997* Columbia *mission.*

The sun is setting low over Lake Powell in the Utah desert. The colors change gradually from iridescent reds and oranges high on the canyon walls to a gray mist above the water. Islands of sandstone cliffs rise in the water, beckoning explorers. I imagine flying the surrounding ridges and canyons in a small airplane, and think what a spectacular place this would be to camp in. I have chanced upon this view while looking down from an airliner.

The deserts of Earth from 200 miles high lure me in the same way. On our sixteen-day flight in late 1997 in the shuttle *Columbia*, we made more than 250 orbits of the planet between 28 degrees south of the equator to 28 degrees north, affording us the opportunity for sightseeing on a global scale. I remember vividly the progression of water and land.

Flying eastbound over the Atlantic, the deep green of the water lightens as we reach the African continent. The contrast between the green water and the light brown sands of the western desert is stunning. Land here looks naked and alien. The unusual ring structure of a naturally uplifted dome, Richat, lies like a whirlpool of frozen sand in the Western Sahara. Farther east, the Pic Touside volcano in the Tibesti Mountains of Chad, the westernmost active volcano in Africa, rises like a marker in the desert announcing "Nile ahead." Irrigating fields along its length, the Nile meanders north, a lifeline in the stark Sahara. The rectangular irrigation patterns along the shore are easily visible in different shades of green. The ancient city of Khartoum, at the confluence of the Blue and White Niles, is the greenest city in the region. Southeast of the Tibesti, the Aorounga impact crater is harder to spot as it lies camouflaged in the Bodele desert, striated by sands and winds for 345 million years.

Continuing east, the folded ranges of the Zagros Mountains in Iran look as alien as Mars. Their color varies with the time of the day from a dull gray to a light brown. The maze of the Makran range and Harboi hills in Pakistan gives way to the magnificent Himalayas, covered with snow. To the north, the Tibetan plateau is dotted with hundreds of emerald lakes. We use the "bow-tie" lake to start looking for Mount Everest and the C-shaped lake, Yang-Cho Yung Hu, to declare that we have missed it. Later, we can easily point out Mount

Kalpana Chawla aboard the space shuttle Columbia, *January 2003.*

The Richat structure, a dome of uplifted sediments in the western Sahara (above); the Ganges delta (opposite).

Everest, especially in the early morning sun, when shadows are long, and the three-dimensional effect is prominent. Abundant glaciers look like giant snow slides running down in all directions, all seeming to halt abruptly, some in translucent pools of blue ice. It is easy to see where the Brahmaputra turns south and then west and joins the Ganges to flow to the Bay of Bengal. The delta of the Ganges is a serene mating of a river with an ocean, with a vivid contrast between wild and irrigated parts. The landmasses, islands, and shoals in the South China Sea are scattered like jewels. The barrier reef around the northeast coast of Australia looks like an emerald necklace in the noon sun.

As we orbit around Earth, the colors on the surface change shades from day to night, but the sky is always pitch dark. We can easily see the atmosphere clinging to the horizon—a very thin layer, especially at sunrise when the colors in the eastern horizon change rapidly from violets to oranges and reds. Sunsets are equally dazzling. The moon races across the sky to the western horizon just after sunset. The horizon changes from a kaleidoscope to a spellbinding silver glow in just a few minutes.

We can't catch all of these sunrises and sunsets and moonrises and moonsets. Often, the only time we are free to float by the flight deck windows is just before or after the eight-hour sleep period. Most of the research on the ship is done in the mid-deck, where there is only one small circular window.

Prior to the flight, I promised myself to look at Earth during one complete orbit. The opportunity comes late in the flight. As I float at the windows in the flight deck, continents and oceans move by. South America is covered with thunderstorms as sprays of lightning shimmer through the clouds.

Twice on my flight, while everyone else is asleep, I float out of my sleep station to the mid-deck window and remove the metallic cover. An ocean dotted with atolls and shoals and rings of reefs enclosed in other ring formations moves by. I think about sailors on great ocean voyages urged onwards by the unknown. About ten minutes later, we have moved over the night side of the planet. I replace the window cover and float back to my station. The mid-deck is dimly lit with the lights of our plant-growth facility. I close the door of my station and instantaneously it is pitch black. Hanging motionless in mid-air, I soon lose awareness of my orientation.

Prior to the flight, I promised myself to look at Earth during one complete orbit. The opportunity comes late in the flight. As I float at the windows in the flight deck, continents and oceans move by. South America is covered with thunderstorms as sprays of lightning shimmer through the clouds. Here and there, as clouds give way, I can discern the coast and make out small settlements by their lights. The Earth, a curved dull-black dome below us, looks alive in its display of lights. Stars hang everywhere in the sky, some clearly farther than the others, hardly any twinkling. Crewmate Takao Doi hands me binoculars and guides me to M42, a nebula in the Orion constellation. It looks like a far-away green castle, and our spaceship, a white chariot, seems bound for it.

An hour and a half later, we are almost back where we were. It has taken us just 90 minutes to cover the whole planet. Just 90 minutes! The realization that Earth is such a small planet is overpowering. It almost looks like a campground, luring space explorers with colors of life. I think of the song of the whales, the calls of wildlife, the trees waving their branches in winds. I feel we must search for another campground. Mars perhaps? The moons of Jupiter?

—Kalpana Chawla was a light-aircraft pilot, an aerospace engineer, and an astronaut. "In her dreams," she once wrote about herself, "she has flown over Valles Marineris and Olympus Mons, the grand features of Mars; she hopes Earthlings will have a chance to experience these destinations firsthand."

NASA (3)

Launch Count: 15,000 Drones, One Babe

"Our entire backyard was taken up with radio transmitters and receivers," says Reg Denny Jr., recalling what it was like to grow up on Vine Street in the hills above Hollywood. "My father strongly believed in his invention, in spite of many people referring to him as 'that crazy actor.' "

Reginald Denny Sr. debuted in silent movies after a stint as a British pilot in World War I. In a career spanning 130 films—everything from *Anna Karenina* to the 1960s' *Batman*—his celebrity waxed and waned, but his devotion to aviation never wavered. And while he enjoyed buzzing the lots at Universal in his Curtiss Jenny, his real interest was the embryonic science of radio control.

During the 1930s, anti-aircraft gunners practiced marksmanship by firing at target sleeves—essentially huge windsocks towed behind a doddering biplane. Strategists doubted real enemies would oblige with such broadside targets and worried that overzealous recruits might down the towplane. In 1935, Denny heard an anti-aircraft officer bemoan the target sleeve's inadequacies. "I told him I saw no reason why a target plane couldn't be sent up by radio control," Denny later told a reporter for the *Los Angeles Herald Express*. "And that was the beginning."

No one had yet flown a model airplane by radio. Denny converted his home workshop into a remote piloting lab. "My dad devoted most of his time to the development of radio control," Reg Denny says, "and took acting jobs only to support his family and the drone project." With a ham radio operator and Walter Righter, a Burbank engineer who built the two-cylinder engine, Denny produced the first radio-controlled miniature target drone, the nine-foot-wingspan RP-1 ("RP" for "Radioplane"), with toy-train motors operating control surfaces and a rotary telephone dial to encode signals in the RC transmitter. The glitchy technology proved more radio than control—"None of it functioned properly," Reg Jr. says. Undeterred by repeated crashes, Denny financed prototypes by playing movie roles opposite the likes of Greta Garbo and Abbott and Costello while the late-night R&D continued on Vine Street.

By 1939, the homebuilt servos were replaced with Bendix units and a joystick replaced the phone dial. When the 12-foot-wingspan RP-4 finally auditioned for Army brass, however, its big break was nearly a disaster. "Unbeknownst to the military that day," Denny's son recalls, "the aircraft went completely out of control. They were extremely impressed with the wild aerobatics, while my father and his group were terrified that the drone might dive into the reviewing stands." RP-4 spun into the turf, but Denny returned to Hollywood with a government contract.

The Army designated the perfected RP-5 the OQ-2, while the Navy named it TDD-1, for "Target Drone Denny." Denny's specs provided for a one-hour flight to 5,000 feet, then a parachute landing "without undue damage." In June 1940 the Radioplane Corporation relocated from household quarters to a Van Nuys factory. During World War II, nearly 15,000 Denny drones were produced, with the OQ-2 followed by the OQ-3.

Until its inevitable encounter with an artillery round, a drone's life expectancy averaged five flights. Of the 9,000 OQ-3s deployed, only six were intact by war's end. Denny continued to refine his designs, adding aileron control and larger powerplants. The final iteration was the long-lived KD-2R5 drone; production of it would exceed 85,000, surpassing that of any full-size aircraft ever manufactured.

Reginald Denny's fortunes were less multiplied. Nearly bankrupt from self-funding his remote-piloting research, and his movie career in decline, he acquired partners, and on disastrous advice, he sold them his share of Radioplane shortly before they consummated a lucrative merger with Northrop. Though Denny is credited with fathering the robot plane, financial straits dictated that his last years would be spent not parenting prototypes but on Broadway, reprising the role of Colonel Pickering in *My Fair Lady*.

DAVID CONOVER

"The hardest work I've ever done," recalled one young lady at the RP factory.

Denny combined his show biz and aeronautical endeavors for one final contribution to his country. In 1945, hoping to bolster troop morale, the War Department commissioned a documentary featuring women working in military factories. David Conover, a cameraman in the Army's 1st Motion Picture Unit, was assigned by unit commander Ronald Reagan to shoot footage of female Radioplane workers. One shift worker stood out in his viewfinder. Nineteen-year-old Norma Jeane Dougherty slapped dope on OQ-3 drones—"The hardest work I've ever done," she later recalled. Conover got Denny's permission to photograph her ("Am I really photogenic?" she asked) and later helped her swing a contract at a modeling agency. This first exposure to the adoring eye of the camera emboldened her to ditch the day job, and her name: Goodbye, Norma Jeane—hello, Marilyn Monroe.

—Stephen Joiner

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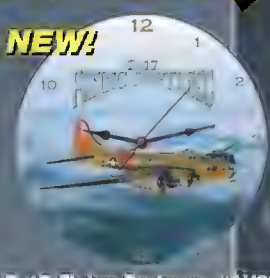
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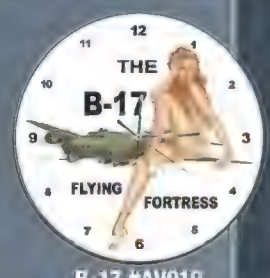

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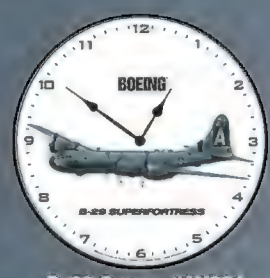

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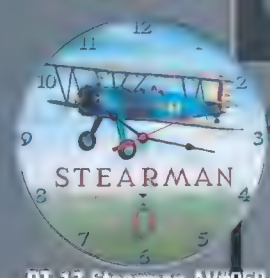

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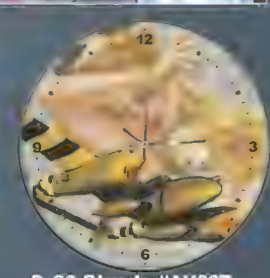
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B-25 Mitchell #AV038

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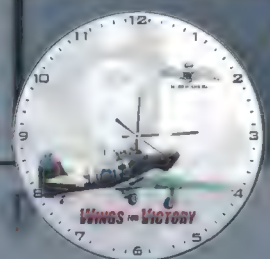

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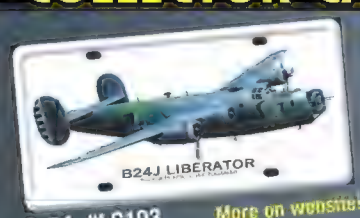

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STRATEGY

PULL UP, DROP, RUN FOR IT.

BY MARSHALL MICHEL

AT AN AIR FORCE FIREPOWER DEMONSTRATION HELD at Eglin Air Force Base in Florida on May 7, 1957, a silvery swept-wing Boeing B-47 Stratojet bomber roared in low at 500 mph before a crowd of more than 3,000 people. The six-jet bomber tore past the front of the reviewing stand, which was filled with high-ranking military officers and 11 state governors, then pulled up into a steep climb and continued up, up, until it was almost standing on its tail. The bomb bay doors snapped open and an orange practice bomb, trailing smoke from a pyrotechnic device in its tail, arced up and away from the bomber.

The audience watched transfixed as the B-47 continued until it was upside down at the top of a half loop. Then, still inverted, it started down the back side of the loop, rolled right side up, and dove away in the direction from which it had come. This was the first public demonstration of a B-47 performing a new mode of nuclear weapons delivery that had been developed far from public view five years earlier. Not just the B-47 but a long list of tactical fighter-bombers would employ the startling new maneuver, which was called toss bombing.

In 1952 the Strategic Air Command had identified more major targets in the Soviet Union than it had heavy bombers to deliver nuclear weapons; because of the aircraft shortage, many targets would go untouched—at least in a first wave of an attack. But about that time two technologies came along that made it possible for short-range fighters to deliver nuclear bombs: mid-air refueling and nuclear weapons that were dramatically lighter in weight than the ones developed during World War II.

SAC had several wings of Republic F-84 Thunderjet fighters, and in July 1952, it assigned some of these units to "strike with atomic munitions…enemy airdromes, guided missile launching sites, key radar control centers, and other suitable targets deep in enemy territory," according to a July 19 message from U.S. Air Force Headquarters. SAC planned to fly F-84s from the United States to Europe, refueling along the way. Once at their European bases, they would take on nuclear weapons and fly to their Soviet targets. The F-84s lacked precision navigation equipment and bombsights, so SAC ordered the pilots to train in low-level navigation. Each pilot got a file folder with details about each target to commit to memory. They would fly to their targets at low altitude—just hundreds of feet off the ground, well below the persistent European overcast. The units practiced navigating over routes in the United States and Europe with terrain similar to that of their assigned wartime targets; they used visual navigation techniques based on time, compass heading, and references such as rivers, cities, roads, and bridges. The fighter-bombers' low altitude had an important if unanticipated benefit: They'd be beneath Soviet radar coverage.

But the low approach to the target also presented a major problem. How could the fighters escape the massive blast, flash, and radiation effects of their own nuclear weapons? SAC's big bombers dropped their bombs from 30,000 feet or higher and turned away, so by the time the bombs detonated they were a safe distance. When a fighter-bomber made a low-level delivery, it did not have enough time to escape before the bomb detonated.

Although few detailed unclassified records of the roots of the program can be found, this much is known: To solve the problem, SAC, working with the Air Research and Development Command, embarked on a program called Project Back Breaker. The attacking airplane would approach the target at high speed and low altitude, then climb sharply and release the bomb so that it was lofted, or tossed, high in the air (about 18,000 feet above the ground, it was calculated). While the bomb was arcing upward, the attacker would continue up into a half-roll, half-loop that formed the first half of a maneuver called a Cuban Eight, and then escape the way it came.

To deliver the bomb relatively accurately, ARDC developed a system known as the Low Altitude Bombing System (LABS), which was a set of gyros and a rudimentary mechanical computer linked to a fist-size, circular cockpit instrument, the dive-and-roll indicator. The equipment weighed only a few pounds, was easily installed, and al-

USAF MUSEUM

most immediately available, and it could consistently hit a circle with a radius of 1,500 feet. With nuclear weapons, as with horseshoes, close counts.

Operation was simple. The pilot had a set of very precise maps from which he selected a visual point on the ground, called an initial point (IP), close to the target. The pilot loaded the time from the IP to the target into the LABS prior to the mission. After takeoff, he visually navigated to the IP, and the instant he crossed over it and began his run to the target, he pressed the bomb release "pickle" button to activate the LABS, then fixed his attention on the dive-and-roll indicator.

The dive-and-roll indicator had two needles, a horizontal one for pitch and a vertical one for direction. When the aircraft reached the calculated release point, about two and a half miles from the target, the needles cued the pilot to climb and guided him to the release point. Les Frazier, an F-100 pilot who flew many LABS missions, describes the sequence this way: "Just prior to the pull-up point, the horizontal needle on the LABS dropped down, and the pilot pulled back on the stick to bring the needle back to level. The horizontal needle led the aircraft into a 4-G climb in two seconds, while the vertical needle showed the course. Keeping both needles centered kept the aircraft lined up, and for several seconds this was the pilot's entire world—it was about as easy as pushing an oyster into a slot machine. The bomb released automatically with a loud *wham* that could be heard in the cockpit, and the airplane would oscillate from side to side as the weapon was blown clear."

In November 1952, SAC had two of its F-84 wings test two different LABS release methods. The first was the basic toss, described above. The advantage of the basic toss was that there was no need to fly over a heavily defended target. But it required a visual landmark close to the target and forced the attacker to follow a fixed course to overfly that landmark.

The second type of release was dubbed the "over the shoulder" maneuver. The attacker flew directly over the target and pulled up into a loop, and as the fighter approached the top of the loop, the LABS automatically released the bomb. After release, the pilot continued the loop as the bomb kept climbing. Well before the bomb reached the apex of its climb, the attacker started back down, rolled upright, and headed back in the opposite direction to escape the blast. The loop over the target made the fighter very vulnerable to close-in defenses, but as long as the target could be seen, the fighter could approach it from any angle, so the method was more flexible tactically than the basic toss.

SAC chose the over-the-shoulder maneuver as the preferred means of delivery, with the toss method an alternative if useable landmarks were available. In January 1953, just three months after the tests began, SAC's fighters officially became part of the strategic force assigned to strike targets in the Soviet Union. Beginning in August 1953, SAC regularly deployed its nuclear-capable F-84s to Europe, refueling en route, and by 1955 it had built this force to over 550 fighters organized into six wings.

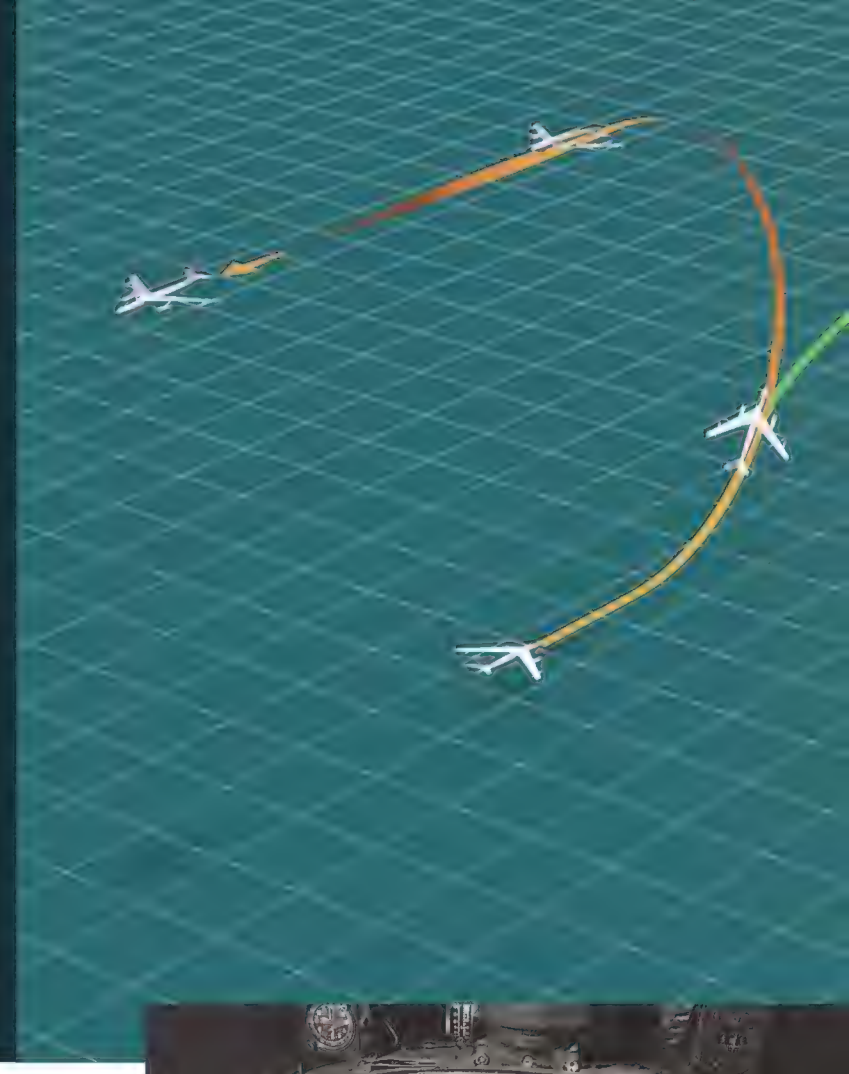
But throughout the early 1950s SAC still considered the Boeing B-47 bomber its primary nuclear weapons delivery aircraft. When it entered operational service, its six jet engines and thin swept wings gave it speed and high-altitude capabilities that enabled it to outrun any fighter in the world. By early 1954, though, it was clear that it was only a matter of time before Soviet surface-to-air missiles and MiGs with heat-seeking air-to-air missiles would shut the B-47 out of the high-altitude environment. The bombers would need new tactics to reach their targets. Fortunately, the B-47 had not only high-altitude performance and speed but also excellent maneuverability.

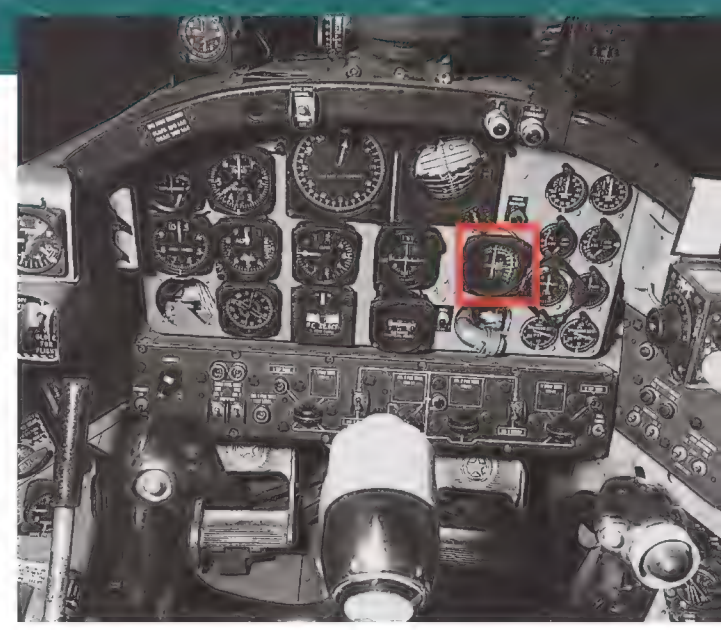
Lieutenant Colonel Doug Nelson of SAC devised the low-level penetration and toss tactic for the B-47 and reportedly startled the SAC staff when he briefed them on the technique. Nonetheless, in early August 1956, SAC asked Boeing to look into the matter, and Dick Taylor was chosen as the company's test pilot for the project.

After practicing with barrel rolls, Taylor first tried the half-loop, half-roll of the Cuban Eight in the big jet bomber in October 1956. He remembers, "Forty seconds—that's the time it took to put

How It Worked

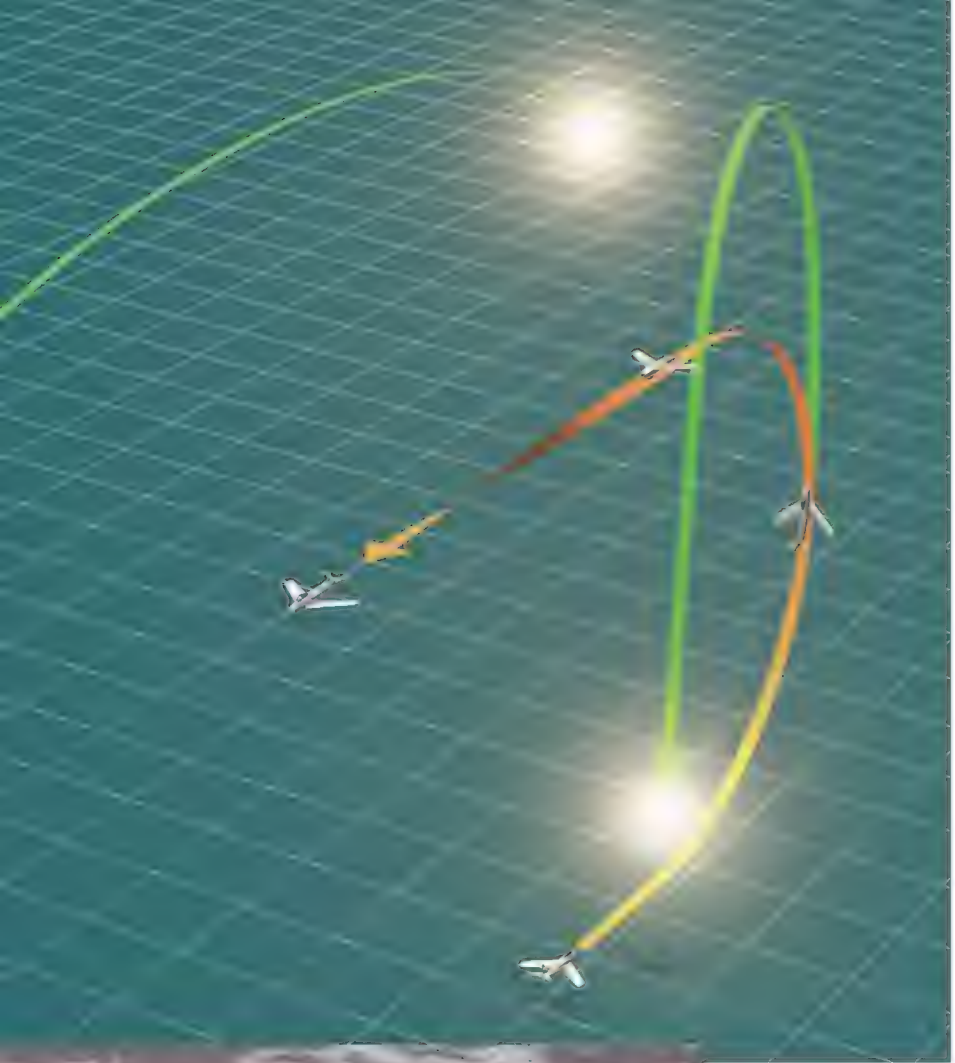
A basic toss maneuver (left) lobbed the weapon a considerable distance from the release point, and therefore the pilot needed an offset visual reference from which to time the start of the climb and the release. The "over the shoulder" method (right) used the target itself as the visual reference, so the attacker could approach from any direction to avoid defenses. The Strategic Air Command chose the "over the shoulder" maneuver as its preferred means of delivering nuclear weapons.





The Low Altitude Bombing System, or LABS, indicator (highlighted) provided climb and heading cues...

TOP: JOHN MACNEILL; BOTTOM: ROBERT MIKESH (2)



...so that the Martin B-57 Canberra could loft its payload accurately. Pulling 3.5 Gs going up, the -57 could toss a bomb 9,000 feet high.

the B-47 through the half-loop and half-roll. But it seemed like an eternity. For those 40 seconds, I could see nothing but blue sky from the pilot's seat. After what seemed like hours, I was certainly relieved to see a horizon again. It proved for the first time that a medium bomber, the B-47, had the stability, power, and maneuverability necessary for the toss-bombing tactic."

Boeing assured SAC that the maneuver, properly flown within the 3-G structural limit, was safe. The next area of concern was the stress of low-level rough air hammering the B-47; its slim, flexible, 116-foot-span wings were considered especially vulnerable. Air Force test crews began flying low-level missions, but during the last phase of testing one of the bombers crashed soon after takeoff. No evidence linked low-level flying to the crash, and after a brief halt the tests continued.

The B-47s proceeded to subject the LABS system to weapons delivery testing, flying the toss maneuver first at minimum weight, then increasing the weight until the last run was at the airplane's maximum gross weight, 130,000 pounds. In June 1955, a B-47 tossed a 6,000-pound dummy nuclear weapon from a 2.6-G pull-up into a half Cuban Eight, and later tossed an 8,850-pound dummy bomb using the same maneuver. The maneuvers proved easy to perform, and the LABS functioned well. By December 1955, SAC was sufficiently satisfied with the tests to assign three B-47 wings to initiate a low-level-flying and LABS training program called Hairclipper.

The maneuver was "either a bomber pilot's dream or nightmare," recalls Sigmund "Alex" Alexander, former president of the B-47 Association, and the crews initially viewed the new tactic with some apprehension. Stewart Frasier, a B-47 bombardier/navigator stationed at Schilling Air Force Base in Kansas, remembers first hearing about it when he and his squadron returned from temporary duty in England. "They announced we had a new bombing plan," he recalls. "Then they showed us a short film of the B-47 LABS maneuver. We were surprised, to say the least, and there was a lot of concern among the crews. The wing commander heard about this concern, and a couple of days later he ordered all the air crews to assemble near the runway at high noon. He flew down the runway low and fast and then pulled up, over and down into a [half] Cuban Eight to demonstrate it could be done and the wings wouldn't break."

B-47 pilot Fred Lange flew a number of LABS training missions from MacDill Air Force Base in Florida. He recalls that the first LABS maneuver he flew with an instructor scared him "because the airspeed going over the top was very slow just before starting the half-roll. In the maneuver, the main thing I tried to do was to lock my knees and not work the rudder pedals to keep the aircraft lined up on a straight line and make a perfect maneuver. I was afraid that the rudder might fail—it was the weakest control surface on the B-47. [But] it just didn't matter whether we flew a perfect maneuver. I got used to it, and the real fun part of the missions was doing aileron rolls on the way to the bombing range."

In an actual operation, the B-47 approached the target at very low level while the navigator/bombardier located the target on his radar, computed the pull-up range, and put the solution into the pilot's LABS timer. At the point where the maneuver was computed to begin, a light on the pilot's LABS instrument came on and the pilot followed the needles into a 2.5-G pull-up. When the bomb released automatically, the pilot reduced back pressure on the control yoke to keep the B-47 right on the edge of a stall buffet as the bomber went over the top upside down at 85 knots, pulling a third of a G or less and flying on thrust alone. Once the aircraft had come out of the top of the maneuver and was diving, the pilot rolled upright as the copilot called off airspeed to make sure the aircraft did not exceed 400 knots in the dive—any faster and the B-47 suffered aileron reversal, a condition in which a deflection of the aileron tended to flex the wing in the opposite direction and roll the airplane the wrong way.

Overstressing the aircraft as it pulled out from the dive was a major concern—the B-47 had a structural limit of 3 Gs, and exceeding it risked catastrophic structural failure. B-47 pilot Robert Winn recalls, "There was nothing like flying along beside another B-47 and watching it start its LABS pull-up. The fuselage actually started to

bend in a U-shape as the aircraft reluctantly entered the maneuver."

In practice, the missions presented new challenges. The navigator sat in the nose of the aircraft with virtually no outside view. Stewart Fraser notes: "Navigation for toss bombing in the B-47 was very difficult, especially at night. The aircraft bounced a lot at low level, and sometimes it was too rough for celestial navigation, too low to use the radar, and we were flying too fast for visual navigation. Often we just flew course, time, and distance.

"One night we got completely lost over Texas and did our pull-up over Dallas instead of the nearby range," he recalls. "Fortunately, we didn't hit anybody over Love Field, but at that point I decided my mother loved me more than the Air Force did, so I got out."

In the first year, accidents began to plague the Hairclipper program. One B-47 crashed on a bombing range in Florida, another failed to roll out of a LABS maneuver in time, and a third, with three instructors on board, crashed at night off the coast of California during a practice mission. Then, in early 1958, things began to come apart, literally, for the B-47 fleet. Six aircraft flying low-level missions were lost when wings came off. All B-47 low-level training, especially LABS, was suspended. Examinations revealed fatigue cracks in the "milk bottle" bolts (so named because of their shape) that joined the wing to the fuselage. The cracks were found on virtually all the B-47s that flew low level, and the culprit was suspected to be LABS. It was finally determined that LABS units had no more problems than any other, and the B-47 that Boeing regularly used for LABS tests had no fatigue cracks at all. At the time, however, structural analysis was very unsophisticated, and to this day unfounded rumors persist that the LABS maneuver was responsible for many of the crashes.

The Boeing B-47 Stratojet was the largest aircraft to fly the spectacular LABS maneuver.

BOEING

In the end, it became a moot point. While LABS training was suspended, new nuclear weapons were coming into the inventory that did not need to be tossed. And the new B-52s were better suited to low-level flying than the B-47s. These developments, combined with the accidents, led to LABS being dropped from the B-47 repertoire.

In mid-1957, while the B-47s were still fully involved with LABS, SAC turned all of its fighter-bombers and their nuclear mission over to the Tactical Air Command. TAC crews sat nuclear "Victor alert" around the world and continued training to use the over-the-shoulder maneuver, which the pilots dubbed "the idiot loop." The nuclear-capable F-84s were replaced by more advanced fighters, mainly the North American F-100s, which became the mainstays of the Air Force tactical nuclear attack fleet. By this time, the term "LABS" began to be applied loosely to virtually all low-level nuclear loft deliveries, not just those that used the mechanical LABS instruments.

While the F-100 performed considerably better than the F-84, the LABS on the aircraft was somewhat quirky. F-100 pilot Les Turner recalls how difficult it was to adjust: "The LABS gyro was in a place were it was impossible to see, so the pilot had to use a small mirror to set in the proper numbers for his mission," he says. "The best was a common dental mirror...and when a dentist or technician left the room with a pilot in the chair they had to take their mirrors with them or the mirrors would disappear. I still have my dental mirror and no, you cannot borrow it," he adds with a grin.

The system's location was not the only quirk. The F-100 introduced a link between the LABS and the fighter's autopilot to give an automatic pull-up, called "auto LABS," a feature that was not particularly popular. F-100 pilot Andy Stallings remembers, "I was having trouble performing the LABS maneuver well. Little things had a large effect on where the bomb would hit—you could pull too slow, or too fast, or, if you could, overshoot or undershoot 4 Gs and so on. Our weapons officer suggested I try 'auto LABS' to see what the maneuver looked like when it was properly performed. In 'auto LABS,' the autopilot had to be turned on at low level, and the F-100 autopilot was notoriously unreliable. The possibility of getting a nose-down command from a malfunctioning autopilot at 100 feet doing 500 knots made most pilots avoid engaging it, but I was young and indestructible. I tried it; it worked and worked well. But once I got the picture of what the delivery should look like, I didn't use the autopilot."

The 1950s also marked a period of competition between the U.S. Air Force and the Navy over the nuclear mission. The large Navy bombers—the Lockheed P2V Neptune, the North American AJ-1 Savage, and the Douglas A3D Skywarrior—were too big to do the LABS maneuver, but smaller Navy jet attack aircraft had the power to fly LABS maneuvers similar to the ones Air Force fighter-bombers used.

One early Navy nuclear delivery aircraft stood out in sharp contrast to the Air Force's aircraft: the propeller-driven Douglas AD Skyraider. At about the same time the Air Force began to develop a way for its fighters to deliver atomic weapons, the Navy began to plan nuclear deliveries using the Skyraider, mainly because of its extremely long range. The ADs' targets were as much as 2,000 miles away, and in the test program ADs flew as long as 13 and a half hours to see how the flights affected the pilots. As a result, the nuclear Skyraiders were modified with relief tubes and extra seat cushions, and the pilots carried a supply of aspirin for headaches caused by wearing their helmets for such a long time.

Pilots took their training for the nuclear missions seriously, and fliers assigned to the slow-flying "Able Dogs" called their training missions "Sandblowers" because the ADs flew so low that when they crossed the coast they kicked up sand. AD pilot Ralph Davis says, "The carrier flight deck was 85 feet high. We'd drop down after we took off and not climb back to that height again until we returned to land." W.R. Wilson, who flew ADs off carriers in the Pacific, recalls, "We practiced penetrating coastal defenses from 200 to 300 miles at sea on a routine basis. Some of the more spectacular missions were when we launched near typhoons in the belief that the trusty AD could penetrate such storms, attack the target area, escape the blast, and return to the ship. To everyone's amazement, we actually [flew through storms and returned] several times during training exercises in the 1950s."

In addition to the standard free-fall bombs, the ADs carried a weapon called the Bureau of Ordnance Aircraft Rocket (BOAR), which was a Mark 7 nuclear bomb with a rocket motor attached. It was made for the AD to loft with the LABS system, but it was not popular with the pilots. Skyraider pilot Tom Beard called the BOAR "a real killer. To deliver it, we would pull up to about a 45-degree climb until the rocket fired, then we would go into about a 135-degree roll and pull through to supposedly escape from the ensuing fireball. I always wondered if they figured that right. In the maneuver we were at about 1,400 feet inverted, and at night or in low visibility it was easy to split-S into the ground."

Air Force fighter pilots watching the slow ADs practicing their LABS deliveries were fascinated. "I was the range officer one day watching F-100s practice LABS, coming about 450 knots on the deck," F-100 pilot Mark Berent remembers. "Then this Navy AD Skyraider guy comes putt-putting along at—what, 150 knots? Then, over the bull's eye, he pulled up and in a flash was going straight up, putt-putt, release, roll and dive away—all in seconds, it seemed. But he seemed much closer to the bomb than the F-100s."

Dick Howard, a Navy AD pilot, learned first-hand that his aircraft would have had a hard time escaping from the blast of its nuclear bomb: "In 1959, my air group was allowed to do a training drop of a real, live, honest–to-goodness Mark 7 nuclear bomb that had exceeded its shelf life. The nuclear material was removed from the warhead, but everything else was operational, including the radar fuse, which was set for a 1,100-foot air burst. I was chosen for the mission. I took off, found the target, then pulled into the loft. The weapon released as planned. As I came over the top of the idiot loop, I looked back over my left shoulder to see what I could. The bomb detonated as promised at 1,100 feet, but it was not more than 1,100 feet from my aircraft! If it had been a nuclear explosion, I would have been in the fireball and wouldn't have had a chance."

For years, U.S. Air Force and Navy tactical crews practiced LABS maneuvers day and night, often in marginal weather, and people died in training. Most of the pilots felt that if they ever had to go to war and use the LABS, it would be on a one-way ride. Navy aviator Tom Beard summed it up this way: "We thought we were on suicide missions. Perhaps we all were—even the Air Force. Crazy days!"

The spectacular LABS toss and over-the-shoulder maneuvers were phased out as Soviet defenses improved. During the time it was employed, the LABS was used by a wide variety of Air Force and Navy fighter-bombers and by Germany-based British Canberra strike squadrons, which formed part of the British Nuclear Strike Force. But the LABS deliveries conducted by the B-47s are the ones best remembered. That great soaring half Cuban Eight was—and remains—the most spectacular maneuver ever performed by a large bomber.

This B-47 wearing heavy makeup was wrung out by Boeing pilots Jack Funk (left) and Dick Taylor.

BOEING

Flying a 1969 training mission with the Air National Guard unit based in Milwaukee, Lieutenant Colonel Paul Poberezny orbited an expanse of rural Wisconsin. Looking out the window of his KC-97 tanker, he concluded that the several thousand acres of verdant pasture below would suit his purposes perfectly. For 40 minutes he circled the area, memorizing the roads, railroad tracks, lakes, and rivers of the site, 85 miles northwest of Milwaukee: Oshkosh.

by Mark Huber

HOW TO DO OSHKOSH

More than three decades later, the name of the town has become synonymous with the world's largest annual celebration of general aviation, hosted by a group Poberezny founded in 1953. The Experimental Aircraft Association has grown into an international organization with more than 170,000 members. It has built its week-long AirVenture into a phenomenon that draws almost a tenth of the globe's general aviation fleet and attracts more than 800,000 participants from around the world. (By contrast, in 1970, the year the event first moved to Oshkosh from Rockford, Illinois, attendance was fewer than 10,000.) "This is the big Disneyland of Aviation," Poberezny says.

Mike Shade, an airframe and powerplant mechanic from Bluffton, Ohio, has come to almost every show since 1977. He and his 15-year-old son plan to fly to the show this year in a 1939 Luscombe. "It's still the only place where you can see everyone, get tuned in to everything that's happening," he says.

Repeat visitors often display patches from each year's show on hats or shirts to show off their veteran status.

"No matter what else is happening in the world, this is the one event I always attend," says U.S. Senator James Inhofe, who has been coming to Oshkosh for 26 consecutive years.

"This is my mecca," says Ron Judy, a pilot and cattle rancher from Gate, Oklahoma, who first started coming to the show in 1978.

Poberezny's son, Tom, now heads the EAA and runs AirVenture. Tom Poberezny is both praised and criticized for transforming the county-fair-like fly-in into a glossy, commercial mega-show, replete with corporate sponsorships. It has become much, much more than a gathering of folks who build airplanes in their garages.

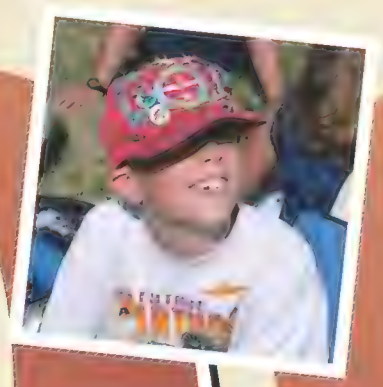
Although the event doesn't start until the end of July (this year's dates are July 29 to August 4), some attendees arrive at the EAA's Camp Scholler (a field southwest of the showgrounds, named for the director of the group's charitable foundation) as early as July 1. The weekend before the event, various activities take place at airports within 200 miles of Oshkosh. T-6, T-28, and P-51 warbirds assemble at Kenosha for a formation clinic and fly-in. Yak pilots do likewise at Manitowoc. Mooney owners congregate at Madison or Watertown. Bonanza pilots rally in Rockford.

Hotel rooms, rental cars, and reasonable air fares evaporate months ahead of time. During the week of the event, restaurants and bars see more than five times their usual number of customers. Overall, the one-week windfall for the local community is an estimated $200 million.

Negotiating an event this size takes savvy. I first went to Oshkosh in 1973; I wish I had known then what I know now, a dozen Oshkoshes later. Want to learn from my mistakes? Read on.

11,000 airplanes, 500 workshops, 800,000 people. How can you see it all?

OSH



LEFT TO RIGHT: JIM KOEPNICK/EAA; ROGER MOLA; DAVID CARLSON; CAROLINE SHEEN; ERIK HILDEBRANDT

CRAIG VANDERKOLK/EAA

Getting There

Most attendees do not fly themselves or ride in light aircraft to the show. They either drive or fly the airlines into nearby Appleton, Green Bay, or the larger terminal at General Mitchell International Airport in Milwaukee, about 90 miles south of Oshkosh. The cheapest fares will be into Chicago's Midway Airport; however, both Milwaukee and the smaller airports are blessed with frequent airline service. The main constriction at any of these airports will be the availability of cars to rent, so book ahead. Tip: Milwaukee and Green Bay have several off-airport car rental firms that are more than happy to help you if the on-airport firms run out of cars.

Road traffic into Oshkosh arrives mainly from the south. From Chicago, on any given afternoon, the Tri-State tollway can tax the patience of even the most seasoned commuter, but especially so on Friday evenings, when regular traffic piles atop Illinois weekend vacationers fleeing northbound. The scuttlebutt is that the Illinois State Policemen tend to ignore speeders.

All that changes at the Wisconsin border. Along I-94, between Kenosha and Mitchell Airport, a fleet of unmarked Ford Crown Victorias sits waiting to apprehend—and fine—speeding motorists. The Wisconsin State Patrol enforces speed limits with gusto. Compounding the adventure, the Wisconsin Department of Transportation has scheduled freeway restorations that threaten to snarl northbound traffic out of Milwaukee for the next four years. Drivers should seriously consider alternate routes that avoid Milwaukee altogether. An enjoyable, albeit lengthy, alternative for attendees arriving from the east is to drive to Ludington, Michigan, and take the car ferry across Lake Michigan to Manitowoc, Wisconsin. From the west, approach through Madison, Wisconsin, and drive up Highway 151. Or better yet, fly.

Aviation's Woodstock, Oshkosh draws thousands to a light-aircraft love-in with something for everyone: Airplane fans stand shoulder to shoulder to watch an amphibian ultralight (below).

FLYING THERE

To capture the true flavor of Oshkosh, arrive in a light airplane. The Federal Aviation Regulations allow passengers of private—non-commercial—pilots to share the cost of a flight. Your local EAA chapter may have a list of pilots in your area looking to cut the costs of flying to Oshkosh by taking a passenger or two. The Federal Aviation Administration publishes detailed Notices To Airmen (NOTAM) about arrival procedures, but basically pilots aim for the tiny town of Ripon, Wisconsin, southwest of Oshkosh, get in line, follow some railroad tracks, and join the swarm arriving at Wittman Regional Airport. This is one of the rare instances when pilots are instructed not to reply to controllers' radio calls. To avoid overtaxing the already clogged special frequencies, pilots acknowledge transmissions by rocking their wings.

In the days leading up to the show, Oshkosh becomes the busiest airport in the world. Think O'Hare is busy? Try 64 arrivals in 15 minutes.

"I always like taking someone along who's never flown in before," says Mike Shade. "Once you get to Ripon, you basically throw the Federal Aviation Regulations about controlled airspace out the window." It is not uncommon to see three aircraft landing on different touchdown points of the same runway at once. On years Shade arrives early, he and a few friends sit in lawn chairs near the approach end of an active runway, watch airplanes arrive, and listen to the chaos on hand-held radios. These are definitely not the types of transmissions heard over air traffic control frequencies in the real world:

"Flight of two, flight of two, c'mon down, c'mon down, cleared to land three-six right."

"Cessna high-wing, keep it high, there's a twin coming underneath you now, put it right down on the numbers if you can."

"Kitfox, follow the T-28. Three-ten, follow the Kitfox on right base."

"Kitfox that just landed, turn into the grass, I've got a twin Comanche following you close."

Controllers are nominated by their supervisors to work at AirVenture and are considered the best, from some of the busiest towers in the country.

"The fly-in procedures are not for the faint of heart," says Shade, "but it's amazing how well it works."

It is not, however, without risk. The National Transportation Safety Board Web site contains 11 pages of Oshkosh-related accidents and incidents, including 30 fatalities. Given the traffic volume over the years, these are statistically insignificant, and the majority fall into the "pilot error" category.

CAROLINE SHEEN; BOTTOM: ERIK HILDEBRANDT

Wittman Regional's tower earns its title: At peak, aircraft land at Oshkosh every 10 to 15 seconds.

Staying There

PACKING

Pack heavy. As evidenced by the overlapping stickers on the merchandise in Oshkosh stores, prices on everything from batteries, film, and snacks to gasoline can shoot up 10 to 30 percent during the week of the event. If at all possible, bring along whatever you will need. Among the essentials: sunglasses, sunscreen, bottled water, batteries, camera and film, cargo shorts, back pack, fanny pack, cell phone, hiking boots, bug spray, compact rain poncho, straw hat, long-sleeve pullover, and lots of cash. You will need these things because Wisconsin's mid-summer weather is highly changeable: boiling during the day, cold at night, and spirited, soaking thunderstorms at a moment's notice.

LODGING

During the show, hotel rooms go for three to five times the normal rate. If you're used to staying in New York City, the rates won't faze you. Several hotels have been built in recent years, but the added rooms still don't handle anywhere near the demand. Fortunately, thousands of residents choose to escape the cacophony, leaving behind empty houses for rent at $60 to $100 (or more) per night per bedroom. The wooded subdivision adjacent to the south end of the airport's Runway 09-27 is a particularly choice location; it allows you to walk to the show and mingle with those in the General Aviation Camping area, not altogether fondly

referred to as "the North 40" for its pasture-like appearance and absence of shade trees. Many residents have been renting to the same conventioneers for years. For those wishing to rent private homes, the EAA maintains a private-housing hotline—(920) 235-3007.

In the midst of all this capitalism, there are a few deals to be had:

The University of Wisconsin—Oshkosh, Lawrence University (Appleton), and several other area schools open their dormitories during EAA week. The rooms aren't air-conditioned and the showers are communal. Still, for an average $40 a night, the dorm spares one the indignity of greeting the day in an overly ripe porta-potty and sloughing through mud in flip-flops to brave the long lines for the camping areas' outdoor shower houses.

The Jesuit Retreat House, south of the airport and next to the EAA's Vette Seaplane Base, along the shore of Lake Winnebago, has been a well-kept secret (until now). Although monopolized by members of World War II's Women Airforce Service Pilots (WASPs) and students from Parks College, the retreat house usually has a few vacancies, although the Jesuits prefer that guests be recommended by someone from the WASPs or Parks. The dormitory-style rooms are single occupancy, and morning Mass is at seven.

Ice, film, ice, suntan lotion, ice... all available at the Barn Store and other nearby establishments.

"This is definitely the best place to stay at EAA," says 82-year-old WASP Ethel Finley of Rehoboth Beach, Delaware. Buses run from the adjacent seaplane base to the showgrounds at regular intervals and are very reliable.

Buses also link the overflow airports of Fond du Lac (15 miles south, aircraft camping permitted) and Appleton (20 miles north, no camping). Aircraft parking spaces at Oshkosh are filled after the first day of the show.

CAMPING

For many, there is no other way to see the show. "Listening to hangar stories by the campfires" is Paul Poberezny's favorite thing to do at AirVenture.

"If you don't camp, you miss half the activity," according to Ron Judy, who flies his Navion up from Oklahoma a couple of days early to get a good parking spot. "If you get there the day the show starts, you'll be parked all the way down in Rockford," Judy warns.

On Thursdays of the event week, Senator Jim Inhofe departs Washington, D.C., and flies himself to Oshkosh, where his two sons already have pitched camp. Inhofe is a commercially rated pilot and owns a stable of aircraft, including an RV-8 kitplane and a Cessna Crusader. "We eat very well when we're there," says Inhofe. "I enjoy the fellowship. We talk about nothing but airplanes."

While most fly-in campers prize spots near the Theatre in the Woods, a large, covered, open-air pavilion adjacent to the vintage aircraft area, Mike Shade prefers the North 40 for its relative quiet. On-site camping runs $17 per night with a three-night minimum. The nightly fee is refundable for early departees, but securing the refund is of-

LEFT: CAROLINE SHEEN; CENTER: ERIK HILDEBRANDT; RIGHT: PHIL WESTON/WESTON IMAGING GROUP

In the vintage aircraft area, a Howard DGA (Damn Good Airplane) serves as a damn good clothesline.

ten more trouble than it is worth (by design, some attendees cynically believe). To use Camp Scholler, which caters to the drive-in crowd—some 40,000 campers—one must be an EAA member.

Near the campground are stores for things like ice, with the markup one would expect from vendors selling to a captive audience. EAA campsites have a prohibition on alcohol that is universally ignored, but you can't buy it on the grounds. There are many private camping and parking areas near the show grounds. Indeed, adjacent property owners make a small fortune peddling everything from bratwurst to bottled water.

SIDESHOWS

Away from the noise of the flightline and the press of the crowds, Oshkosh has plenty to offer those seeking a lower-key experience.

The Vette Seaplane Base is a five-mile drive down Highway 45 (buses run regularly from the main show grounds). Located in a sheltered cove on the western shore of Lake Winnebago, Vette is everything the main grounds are not: quiet, orderly, and bucolic. The manicured pathways from the parking lot to the camping areas are lined with potted geraniums and impatiens. Neatly painted signs warn walkers of poison ivy off the path.

At 7:45 a.m., Lloyd Anderson has been on duty for almost an hour. Waterfront campers begin to stir, emerging from campsites with nicknames like "Parrothead Avenue." The smells of coffee and bacon begin to waft through the humid summer air. Anderson, a retired air traffic controller, is reprising his career for a visitor as he directs seaplanes in and out of the base with a small radio. He stands on a tiny deck at the mouth of a cove surrounded by massive willow trees, 30 moored airplanes behind him bobbing in waters mottled with bright green algae. The aircraft have arrived from as far away as the Bahamas and Alaska's Beaufort Sea. The sky is starting to streak gray, and several departures are being expedited before the weather traps them. Between departures and arrivals, Anderson talks about the Stinson 108 he is restoring in his garage. The engine needs a crankshaft. He has not found one yet. Small skiffs begin to tow aircraft into the docks for loading. Across the cove, at the Jesuit Retreat House, Mass is letting out.

A little closer to the action but still a world away, the grass strip of Pioneer Airport stretches out behind the EAA Museum. A trio of Bell 47 bubble-canopy helicopters whine overhead, spiriting riders around the grounds for $30 a pop. Paul Poberezny built Pioneer Airport to mimic the feel of a small airport in the 1920s and 1930s. "I wanted to convey that charisma of aviation," he says. Within Pioneer's five hangars rest standards like a J-3 Cub and a 1936 Aeronca C-3 Collegian, also known as "the flying bathtub." History is there in such one-of-a-kind treasures as *Little Mulligan*, Harold Neumann's 1941 monocoupe, a cousin of the famous Ben Howard racer *Mister Mulligan*. And there's the Folkerts Henderson High Wing, an early design from Clayton Folkerts, who was later chief designer for Don Luscombe's company.

Seeking serenity? Here's a recipe: an Avid Flyer on floats, lawn chairs on rockers, and a memory swap by the lake.

Posters from 1930s air races and expositions decorate the hangar walls, which support racks of ancient engines.

AT THE SHOW

Parking is the Achilles' heel of the event. If you arrive later than mid-morning or try to leave immediately at the conclusion of the day's performances, you will be stuck in traffic for a long time. General parking is herded into a handful of color-coded fields that can be lengthy and dusty (or muddy) walks from the main show grounds. (Sweet-talking volunteers directing vehicles will not gain you more proximate parking; they've heard it all.) During times of peak load, the police reroute the streets into a one-way racetrack, easing but not dissipating the traffic jams. However, there are a couple of things you can do: Show up really early, or…

Take a shuttle bus. First, park at the Appleton or Fond du Lac airport, the seaplane base, the shopping mall on the west side of the freeway, or the University of Wisconsin dormitories, then take the bus. Some buses are free; others charge a nominal fee. The bus won't get you to the show any faster than a car would, but you won't have to walk as far to the main gate or endure the aggravation. Using the lots at UW-Oshkosh also allows you to bypass the traffic jam that forms at the main freeway show exit (Highway 44).

Park in Camp Scholler. This is tricky; it requires knowing a camper with a pass. But it allows you to exit Highway 26 to the south instead of the "cattle gate" at the Highway 44 exit. Usually, campers don't use all the vehicle spaces allotted to them and someone has an extra pass.

Park at the EAA Museum. There are shuttle buses available from the museum to the show grounds.

Along the northern perimeter of the airport, there are other non-sanctioned places to park, which will become apparent as you drive east down 20th Avenue (Highway 44) and look to the right. Even homeowners not officially selling lawn space can easily be persuaded to accommodate your vehicle for a few dollars and a smile.

GENERAL ADMISSION

If you are inclined to join the EAA anyway, do so months before the show rather than at the show. EAA membership ($40 annually) earns a discount on the admission fee and access to Camp Scholler. For members, the daily adult admission fee is $19; nonmembers pay $29. The weekly fee is $94 for members, $203 for non-members. You can pay the admission fee with a credit card.

With the relocation of the show main gate several years ago, the arduous registration process became much faster, but you can avoid any remaining hassle by showing up on a non-weekend day or a day or two prior to the show.

On the lawn of the Communications Center, airshow fans set up for the next shot…or not.

PHIL WESTON/WESTON IMAGING GROUP

Watermelon whacking (left) is a seaplane base activity. Right: A detail from an Oshkosh map shows why…

…the Poberezneys cruise the grounds in matching VW Beetles (Paul, Red One; Tom, Red 3) instead of hoofing it.

DOING A QUICK RECON

Buy a program, which contains a detailed map, grab a free copy of *AirVenture Today*, and read both before starting out. First-time visitors are almost always unprepared for the scale of the 1,400-acre show grounds.

"Originally, I walked myself to death," says Ron Judy, who now stays close to the vintage aircraft area, which is his main focus at the show. For neophytes, the quickest way to get a feel of the place is to "walk the line" parallel to runway 18-36: warbirds to the north, homebuilts in the middle, vintage aircraft south of them, and ultralights way down at the south end with their own little ultralight runway. West of the "line" are specialized buildings and pavilions, most of which are occupied by vendors, the forum tents, and the static aircraft display areas. Food tents and kiosks selling programs are interspersed within this mosaic.

The grounds are incredibly clean, compared with other events of this size. People who attend don't litter, and the EAA makes it a point to remind first-timers of the fact.

WATCHING THE AIRSHOW

Oshkosh continues to attract the finest airshow pilot performers in the world. Unquestionably, the best place from which to watch them is just south of the performers' tent, located at show center. From there, you can often see the performers "walk through" their pre-show routines; they fly their acts with their hands. You can also catch glimpses of the various celebrities and VIPs invited into the performers' tent. Other good places from which to view the action are the International Aerobatic Club's pavilion and on the hill in front of the control tower.

For those wanting a more exclusive venue, rent a boat and spend the day on Lake Butte des Morts and Lake Poygan (they are connected). The practice aerobatic box is directly overhead—and everyone practices.

SOCIALIZING

More interesting than the airplanes themselves are some of the people you will meet at the show. Legendary test pilot and airshow performer Bob Hoover always makes an appearance, either at one of the forums or at a booth in the exhibitors' pavilions. Ken Hyde, one of the most knowledgeable experts on the Wright brothers' aircraft, will be on hand this year with his reproduction *Flyer* and simulator. Many airshow performers appear at various vendors' exhibits throughout the show. Pilots standing next to their warbirds and vintage aircraft are generally approachable and almost always have interesting stories.

Then there are the more eccentric: Jerry Sleger's homebuilt one-man band near the Theatre in the Woods and Steve Hay's ornithopter, its asthmatic engine chugging down the flightline, his wife Joan clad in animal skin and Viking helmet, perched atop the flapping wings.

Need any wheel pants? Find them and so much more at the Fly Market.

TOP AND RIGHT: PHIL WESTON/WESTON IMAGING GROUP; CENTER: CAROLINE SHEEN; MAPS: EAA

Proud to be at Oshkosh, Julie Clark performs in a restored Beechcraft T-34 to patriotic music. Below: One-man-band Jerry Sleger whistles a different tune.

THE FLY MARKET

Housed in a shabby tent city north of the exhibitors' buildings and west of the control tower is a collection of kitsch not to be missed.

"My favorite part is the Fly Market," confesses Senator Inhofe. "The first thing I do is head to the Fly Market and buy my stuff." Inhofe once found a clock for a Stearman biplane. You can also find a lot of non-aviation-related items: awful hotel wall art, stir fryers, "magic pens," hammocks, hats, hoses, paint removers, drills, anti-bacterial solutions, an endless variety of offensive T-shirts, and a "leather blow-out." In the waning days of the show, peddlers determined to dispose of this "inventory" will often sell out for pennies on the dollar.

RIGHT: MARK SCHAIBLE/WESTON IMAGING GROUP; TOP: CAROLINE SHEEN

FORUMS & WORKSHOPS

The forums harken back to the EAA's roots as a group of builders assembling aircraft at home and are the means by which the tradition of this craft is passed to the next generation of self-airframers. Here you can learn "The Do's and Don'ts of Resins," how to install a Subaru engine in your airplane, and the latest techniques in welding, working with sheet metal, wood, and composites, and applying fabric covering.

The better forums tend to be held earlier in the morning. Past attendees have heard noted aircraft designer Burt Rutan's insights into future aircraft design, gotten an FAA briefing on the latest plans for the national airspace system, or received helpful hints from a flight surgeon on staying fit for flying.

One show favorite is the Dawn Patrol, led by the folks who represent Canon camera equipment. From Canon's small headquarters, next to the EAA media center, a few steps west of the control tower, staff members lead daily photo expeditions very early in the morning when the light is soft, the weather is cool, and the crowds are small.

SHOW FOOD

About the best thing one can say about the on-site food is that it is available and no worse than one would find at a county fair. Prices are about what you would pay at a major sports stadium. Amid the many opportunities to increase your cholesterol, the warm doughnuts stand out: deep-fried as you watch and rolled in sugar and cinnamon, sold in the morning near the International Aerobatic Club's pavilion.

KEEPING YOUR COOL

The important thing is to take regular rest breaks and drink plenty of water. Heat prostration is a common affliction at Oshkosh among all ages. But there are pockets of air-conditioning available. The Bose headphone trailer is one of them (but you have to sit through an infomercial). Another is the Cessna tent (but they will try to sell you an airplane).

The museum would be my first choice. The EAA AirVenture Museum, set well away from the center of the action, houses one of the most diverse private collections of aircraft in the world. The museum giftshop offers the standard books and keepsakes,

ON-THE-TOWN

The flavor of Oshkosh cannot be fully captured within the airport grounds. While the choices are numerous, the following have been recommended by veteran Oshkosh-goers.

HOBBY SHOPS

Dymond Modelsports has one the best selection of remote-control model aircraft in the country and is a perennial favorite for pilots of full-size and scale aircraft alike.

RESTAURANTS

The local restaurants all serve Wisconsin-size—that is to say, huge—portions, and their prices remain

along with odd treasures such as videos of the 1950s "Sky King" TV series.

During AirVenture, noted aviation authors, such as Rinker Buck and ace Clarence "Bud" Anderson, lecture in the museum's theater. It's a welcome respite to slouch in your theater seat, soak up the air conditioning, close your eyes, and listen to tales of flying.

Oshkosh at Night

INSIDE THE FENCE

Night programs feature everything from aerobatic/pyrotechnic shows to polka bands to astronauts who answer audience questions in the Theatre in the Woods. The most fun, of course, is had at the individual campsites, the details of which have been omitted here to protect the guilty.

OUTSIDE THE FENCE

Befriending vendors pays, as they get invited to the best parties and often have extra invitations. These are catered, corporate events, and *Flying* magazine's is the undisputed champ. Past parties have featured pyrotechnic airshows over Lake Butte des Morts and enough chow and booze to placate the 101st Airborne. The warbird pilots host a spirited event Thursday evening at the Fond du Lac Holiday Inn. If you don't make the guest list, a self-guided night on the town around Oshkosh can also provide a cultural education.

The establishment most frequented by fliers is the Acee Deucee, a place reminiscent of Pancho's Happy Bottom Riding Club, the pilots' hangout portrayed in the movie *The Right Stuff* (see "On the Town," below). But the bar at the Pioneer Inn is quiet, civilized, and a good place to grab a nightcap. Airshow performers often stay at the hotel there.

ERIK HILDEBRANDT; BOTTOM: MARK SCHAIBLE/WESTON IMAGING GROUP

Warbird worship: Marine aviators have always said the Chance Vought F4U Corsair was a work of art.

LEAVING

The hardest part of the show is the departure. Even though your feet are aching, your face is sunburned, and your money is gone, you'll be reluctant to leave the land Paul Poberezny first spotted from the air in 1969. Oshkosh is where I began my photo collection of World War II aircraft nose art, first flew in a Ford Tri-Motor, and marveled at the ground shaking beneath my feet as the Concorde raced down the runway. This is the place where I fell in love with Navions, gull-wing Stinsons, Beech Staggerwings, and aerobatics. Whatever you're interested in, it's there. At least once, you've got to do Oshkosh.

At the RCR Split Level Bar, owner Ron Rucks is the main attraction.

reasonable during the show. Want a 32-ounce prime rib? You've come to the right place: It's on the menu at Winemakers. The sandwiches at Friar Tuck's are said to be delicious, as are dinners at both the Granary and the Roxy. Waits for tables at both of these places used to be interminable, but thanks to years of practice on the part of the staffs at both places, now rarely run more than an hour. Be warned, the Roxy is boisterous. If you actually intend to hold a conversation with your fellow diners, the Granary may be a better bet. For something a little different, drive up to Menasha to Los Compadres for authentic Mexican food.

For a slice of past Americana, wheel into Ardy & Ed's Drive-In, where, since 1948, car hops on roller skates take your order. You can enjoy an authentic Wisconsin perch fry at Wendt's, just south of the seaplane base in the hamlet of Van Dyne. Leon's is still the spot for the best frozen custard.

BARS

On any given night during AirVenture, the lines at Acee Deucee are out the door. Stories of Chuck Yeager and Bob Hoover holding court in the back bar are regularly repeated. Last year on the back patio, a band called Redline 7,000 performed unique interpretations of 1960s rock standards such as Jimi Hendrix's "Purple Haze."

At the RCR Split Level Bar, aviation writers and photographers gather in the evening in a real neighborhood saloon, complete with actual neighbors.

Strap In! It's Airshow Season!

Alabama

Bessemer Sept. 13-14
Bessemer Airshow

Cullman Oct. 4-5
Wings & Wheels

Huntsville Mar. 29-30
Airshow 2003/Blue Angels

Montgomery Oct. 11
Maxwell AFB Open House

Alaska

Eielson AFB June 25
Airshow/Thunderbirds

Elmendorf AFB June 28-29
Arctic Thunder/ Thunderbirds

Arizona

Davis Monthan AFB, Tucson Mar. 29-30
Aerospace & Arizona Days/Thunderbirds

Kingman Oct. 4-5
Air and Auto Show

Luke AFB Mar. 15-16
Luke Days 2003/ Thunderbirds

Phoenix Oct. 9-12
Copperstate Regional Experimental Aircraft Association Fly-In

Valle Airport June 21-22
High Country Warbirds Fly-In

Arkansas

Little Rock AFB May 31-June 1
Centennial of Flight Airshow

Fort Smith Oct. 11-12
Fort Smith Regional Airshow/Thunderbirds

California

Broome Ranch June 9
Quiet Birdmen Airshow

Camarillo Aug. 23-24
Camarillo Airshow

Castle AFB May 7-11
All Red Star 2003

Chino May 17-18
Planes of Fame Airshow

Edwards AFB Oct. 25-26
Edwards AFB Open House/Thunderbirds

El Cajon May 2-4
Wings Over Gillespie

Half Moon Bay Apr. 27
Pacific Coast Dream Machines

Hemet May 31
Hemet-Ryan Airshow

Lake View Terrace July 19-20
American Heroes Airshow

Long Beach Oct. 4-5
ShoreFest/Blue Angels, Snowbirds

Marysville June 20-22
Golden West EAA Regional Fly-In

Moffett Field Sept. 13-14
Air Expo

NAF El Centro Mar. 14-15
NAF El Centro Airshow/Blue Angels

Ramona Air Fair May 30-June 1

Ridgecrest Oct. 15
Kern County Airshow

Riverside Mar. 29
Riverside Open House & Airshow

Salinas Oct. 17-19
California International Airshow/Thunderbirds

San Diego Oct. 17-19
MCAS Miramar Airshow/Blue Angels

San Francisco Oct. 11-12
Fleet Week/Blue Angels, Snowbirds

Santa Rosa Aug. 22-24
Wings Over Wine Country Airshow

Van Nuys June 21-22
Van Nuys Aviation Expo

Vandenberg AFB Oct. 1
Air and Space Show/ Snowbirds

Visalia Apr. 26-27
Vintage Years Airshow

Watsonville May 23-25
Watsonville Fly-In and Airshow

Colorado

Colorado Springs May 17-18
In Their Honor Airshow

Longmont June 28-29
Longmont Airshow

USAF Academy May 28
Thunderbirds

Florida

Cape Coral May 15-18
Ft. Myers Beach Airshow

Daytona Beach Nov. 8-9
Embry-Riddle Celebrates Centennial of Flight/Thunderbirds

Ft. Lauderdale May 3-4
Air & Sea Show/ Thunderbirds, Snowbirds

Jacksonville Beach Oct. 25-26
NAS Jacksonville Beach Airshow/Blue Angels

Lakeland Apr. 2-8
Sun 'n Fun EAA Fly-In

NAS Mayport Oct. 25-26
NAS Mayport Airshow

NAS Pensacola Nov. 7-8
Blue Angels Homecoming Airshow/

Orlando International Airport Nov. 22-23
The Great Orlando Rotary Airshow

Patrick AFB Apr. 27
Century of Flight Airshow/Thunderbirds

Pensacola Beach July 11-12
Pensacola Beach Airshow/Blue Angels

Punta Gorda Mar. 22-23
Florida International Airshow - "Centennial of Flight"/Blue Angels

Stuart Nov. 8-9
Stuart Airshow

Titusville Mar. 7-9
Tico Warbird Airshow

Tyndall AFB, Panama City Mar. 22-23
Gulf Coast Salute/ Thunderbirds

Williston Apr. 12-13
Wings Over Williston

Zephyrhills Mar. 29
Zephyrhills Fly-In

Georgia

Atlanta Aug. 9-10
Incredible Age of Aviation

Columbus Mar. 22-23
Thunder In the Valley

Dobbins ARB Apr. 26-27
Dobbins ARB Open House/Snowbirds

Peachtree City Sept. 6-7
Great Georgia Airshow

Robins AFB Sept. 6-7
Robins AFB Airshow

Valdosta Oct. 4
Moody AFB Airshow

Vidalia Apr. 12-13
Vidalia Onion Festival Airshow/Blue Angels

Hawaii

Hickam AFB Aug. 9-10
Hickam Air Force Base Airshow/Thunderbirds

Idaho

Arco July 26-27
Airshow/Blue Angels

Mountain Home AFB Sept. 13-14
Gunfighter Skies 2003/ Thunderbirds

Illinois

Chicago Aug. 16-17
Chicago Air & Water Show/Thunderbirds

Morris Aug. 30-31
Morris Air Show

Mt. Vernon Aug. 8-10
Air Odyssey

Peoria July 4-6
Prairie Airshow/ Thunderbirds

Scott AFB Sept. 6-7
Scott AFB Airshow

Springfield Sept. 19-21
Air Rendezvous

Indiana

Elkhart Aug. 8-10
Elkhart Airshow

Evansville June 26-29
Evansville Freedom Festival

Gary July 18
Gary Airshow

Goshen July 5
Freedomfest

Grissom Aeroplex-Peru July 26-27
Grissom Community Airshow/Thunderbirds

Indianapolis Sept. 12-14
Indianapolis Airshow/ Blue Angels

Madison Oct. 4
Madison Airshow

Muncie Aug. 8-10
Summer Heat Balloon Championship

Richmond Aug. 22-24
Fun In the Sun

South Bend Aug. 15-17
SkyFest Michiana

Terre Haute July 11-13
Terre Haute Air Fair

Valparaiso Aug. 22-24
Porter County Heritage Airshow

Iowa

Burlington Sept. 6-7
Burlington Regional Airshow

Cedar Rapids July 5-6
Fly-Iowa

Davenport June 6-8
Quad City/Blue Angels

Dubuque July 3
Dubuque Airshow

Kansas

Minneapolis July 4
Minneapolis Airshow

Topeka May 10-11
Wings Over Topeka/ Blue Angels

Wichita Sept. 18-21
Wichita Aviation Festival/Thunderbirds

Kentucky

Louisville Apr. 12
Thunder Over Louisville

Louisiana

Barksdale AFB May 10-11
Defenders of Liberty Airshow/Thunderbirds, Snowbirds

NAS JRB New Orleans Oct. 31-Nov. 2
N'awlins Airshow/ Thunderbirds

Maryland

Andrews AFB May 17-18
Joint Services Open House/Thunderbirds

Andrews AFB Sept. 18
Airshow/Thunderbirds

Annapolis May 21
Naval Academy Airshow/Blue Angels

Frederick Aug. 16-17
Wings of Freedom

NAS Patuxent May 24-25
Airshow/Blue Angels

Massachusetts

Fitchburg Sept. 11-14
Autumn Air-Fest

Otis ANGB Falmouth Aug. 23-24
Cape Cod Airshow/ Thunderbirds

Westfield Aug. 16-17
Westfield International Airshow/Blue Angels

Michigan

Battle Creek July 3-6
Battle Creek Balloon Championships/ Thunderbirds

Belleville Aug. 9-10
Thunder over Michigan

Dearborn Sept. 8-24
National Air Tour (Re-enactment of Ford Air Tours)

Grosse Ile July 5-6
Grosse Ile Airshow

Muskegon July 4-6
Muskegon Air Fair/ Blue Angels

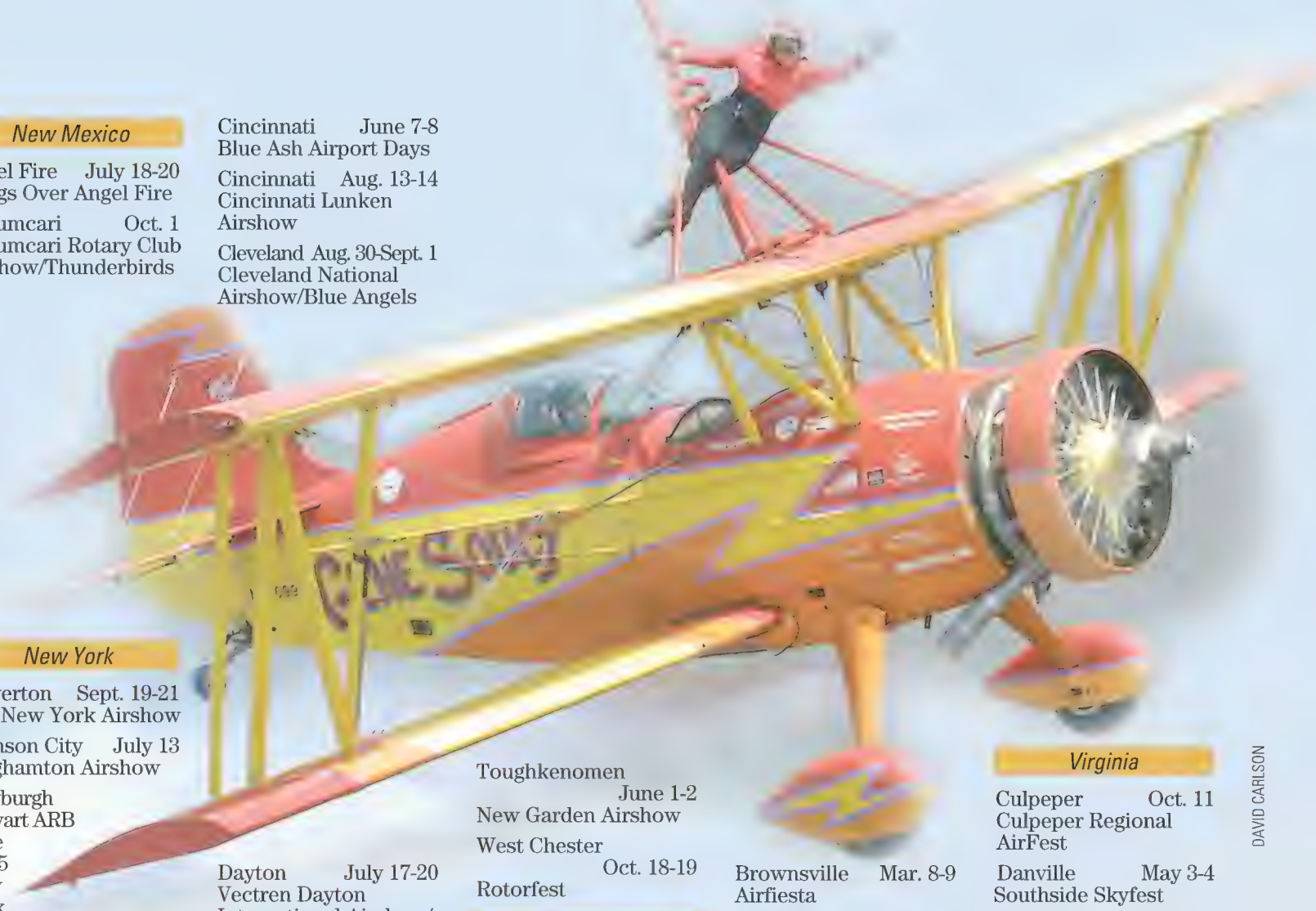
Selfridge ANGB July 25-26
Airshow/Thunderbirds

Traverse City July 5-6
National Cherry Festival Airshow

2003 U.S. AIRSHOW SCHEDULE

Some schedule information provided by International Council of Air Shows (*www.airshows.org*; phone (703) 779-8510). Current as of mid-February 2003. Subject to cancellation, change of date, change of show title, and change of performers. Check local listings and the *Air & Space* Calendar.

AFB Air Force Base
ANGB Air National Guard Base
ARB Air Reserve Base
EAA Experimental Aircraft Association
JRB Joint Reserve Base
MCAS Marine Corps Air Station
NAS Naval Air Station
USAF United States Air Force



DAVID CARLSON

Willow Run Aug. 9-10
Willow Run Airshow

Minnesota

Duluth Sept. 20-21
Duluth Air & Aviation Expo/Blue Angels

Mankato June 7-8
Minnesota Air Spectacular/ Thunderbirds

Mississippi

Biloxi Apr. 12
Keesler AFB Airshow

Columbus AFB May 31-June 1
Wings Over Columbus/ Thunderbirds

Tupelo Sept. 20-21
Tupelo Airfest 2003: The Wright Stuff

Missouri

Cape Girardeau July 11-13
Cape Girardeau Regional Air Festival

Columbia May 23-26
Salute to Veterans Celebration

Columbus AFB June 1
Wings Over Columbus/ Thunderbirds

Joplin June 28-29
Joplin AirFest

Kansas City Aug. 16-17
KC Aviation Expo

St. Louis July 3-5
Fair Saint Louis

St. Louis Aug. 29-Sept. 1
St. Louis County Fair & Airshow

Whiteman AFB June 14-15
Wings Over Whiteman/ Thunderbirds

Montana

Missoula July 12
Airfest Montana/ Thunderbirds)

Nebraska

Fairmont June 14-15
Celebrate 100 Years of Aviation Airshow

Offutt AFB Aug. 23-24
Offutt AFB Open House/Thunderbirds

Nevada

Las Vegas Sept. 19-21
Las Vegas Airshow

Fernley May 17-18
Fernley Fly-In and Air Fest

Nellis AFB Nov. 15-16
Aviation Nation Airshow & Open House Thunderbirds

Reno Sept. 11-14
Reno Air Racing Assn. National Championship Air Races/Thunderbirds

New Jersey

Millville May 17-18
Wheels & Wings Airshow & Car Show/ Blue Angels, Snowbirds

New Mexico

Angel Fire July 18-20
Wings Over Angel Fire

Tucumcari Oct. 1
Tucumcari Rotary Club Airshow/Thunderbirds

New York

Calverton Sept. 19-21
The New York Airshow

Johnson City July 13
Binghamton Airshow

Newburgh Stewart ARB June 14-15
New York International Airshow/Blue Angels

Schenectady July 11-13
ESAM Northeast Airshow

North Carolina

Charlotte Sept. 27
Charlotte Airshow

Fayetteville May 18
Festival of Flight 2003 Airshow

Fort Bragg May 24-25
Fort Bragg/Pope AFB Open House and Airshow/Thunderbirds

Lumberton May 17-18
World Celebration of Flight

MCAS Cherry Point May 2-4
From the Beginning to the Beyond/Blue Angels

Seymour Johnson AFB Oct. 25
Wings Over Wayne

Wilmington Apr. 12-13
Coastal Carolina Air Expo/Thunderbirds

Winston-Salem Sept. 6-7
Winston-Salem Airshow

North Dakota

Grand Forks AFB June 22
Grand Forks AFB OpenHouse/Thunderbirds

Minot AFB Aug. 16
Northern Neighbors' Day

Ohio

Akron June 21-22
Aero Expo 2003: Century of Flight

Ashtabula July 11-13
Gathering of Eagles VIII

Cincinnati June 7-8
Blue Ash Airport Days

Cincinnati Aug. 13-14
Cincinnati Lunken Airshow

Cleveland Aug. 30-Sept. 1
Cleveland National Airshow/Blue Angels

Dayton July 17-20
Vectren Dayton International Airshow/ Blue Angels, Thunderbirds, Snowbirds

Portsmouth June 7
Portsmouth Airshow

Waynesville Aug. 30-31
Red Stewart EAA Fly-In

Wright-Patterson AFB May 10-11
Air Power 2003

Zanesville July 12
Zanesville Airshow

Oklahoma

Claremore Sept. 6-7
Claremore Regional Airport Airshow

Muskogee May 16-18
Airshow Oklahoma

Oklahoma City June 13-15
Aerospace America International Airshow

Vance AFB May 10
Vance AFB Airshow

Oregon

Hillsboro Sept. 20-21
Oregon International Airshow

Portland June 7-8
Portland Airshow

Pennsylvania

Harrisburg June 14
Capital City Airshow

NAS Willow Grove Sept. 13-14
Sounds of Freedom Airshow

Pittsburgh June 20-22
Wings Over Pittsburgh

Reading June 6-8
World War II Weekend

Reading Aug. 16
Reading Aerofest

Toughkenomen June 1-2
New Garden Airshow

West Chester Oct. 18-19
Rotorfest

Rhode Island

North Kingstown June 27-29
Rhode Island National Guard Open House/ Blue Angels

South Carolina

Charleston AFB May 10
Air Expo

Columbia Nov. 7-9
Celebrate Freedom Festival

Florence May 3-4
May Fly Airshow

Greenville Apr. 26
Greenville Airshow/ Thunderbirds

Myrtle Beach May 31
Sun Fun Festival/ Thunderbirds

Spartanburg Apr. 30
Airshow/Thunderbirds, Snowbirds

South Dakota

Sioux Falls June 21
Sioux Falls Airshow/ Thunderbirds

Tennessee

Jackson Oct. 4-5
Skyfest Tennessee

Knoxville Apr. 26-27
Great Smoky Mountain AirFest/Blue Angels

Millington/Memphis May 31-June 1
Midsouth Charity Airshow/Blue Angels

Tullahoma June 21-22
Arnold AFB Centennial of Flight Celebration

Texas

Abillene May 17
Dyess AFB Open House

Brownsville Mar. 8-9
Airfiesta

Burnet Apr. 12
100 Years of Warbirds and Wildflowers

El Paso Oct. 4-5
Amigo Airsho/ Thunderbirds

Ft. Worth-Alliance Sept. 27-28
Fort Worth International Airshow/ Blue Angels

Galveston Apr. 26-27
Spirit of Flight

Gilmer Oct. 17
East Texas Jamboree Airport Open House

Houston Oct. 18-19
Wings Over Houston

Midland Sept. 27-28
Fina-Commemorative Air Force Airshow/ Snowbirds

Millville May 17-18
Millville Airshow

Nacogdoches Apr. 26-27
Nacogdoches Airshow

NAS Corpus Christi Apr. 4-5
NAS Corpus Christi Open House/Blue Angels

New Braunfels May 16-17
EAA Southwest Regional Fly-In

Odessa May 17
Odessa Airshow

Randolph AFB Nov. 1-2
Air Tattoo/Blue Angels

Sheppard AFB June 14-15
Sheppard AFB Open House/Thunderbirds

Slayton May 17
Texas Air Museum Airshow

Virginia

Culpeper Oct. 11
Culpeper Regional AirFest

Danville May 3-4
Southside Skyfest

Manassas Oct. 11-12
Manassas Airshow

NAS Oceana Sept. 6-7
Airshow/Blue Angels

Washington

Arlington July 9-13
Northwest EAA Regional Fly-In

Bellingham June 15
Bellingham International Airport AirFest

Fairchild AFB July 26
Aerospace Day

McChord AFB July 12-13
Airshow/Thunderbirds

Pasco July 26-27
Tri-City Waterfollies

Seattle Aug. 2-3
Seafair/Blue Angels

Tacoma July 4
Tacoma Freedom Fair Airshow

Wisconsin

Janesville Sept. 26-28
Southern Wisconsin Airfest/Thunderbirds

LaCrosse June 21-22
Deke Slayton Airfest/ Blue Angels

Manitowoc June 7-8
Manitowoc County Airshow

Oshkosh July 29-Aug. 4
EAA AirVenture

Westbend June 14-15
Southeast Wisconsin Airfest

Wyoming

Cheyenne July 23
Cheyenne Airshow/ Thunderbirds

Evanston Aug. 22-24
Evanston Airshow

JIM WRIGHT BUILT HIS MILLION-DOLLAR BABY WITH 20,000 RIVETS,

Silver Bullet

BY PRESTON LERNER

A TWIN WASP JUNIOR, AND NO BLUEPRINTS.

The airplane hammers past, 150 feet off the deck, the long polished aluminum fuselage a silver dart against the distant mountains. As it banks gracefully and climbs, it leaves in its wake the signature rasp of its Twin Wasp Junior radial and the collective awe of the spectators at the National Air Races in Reno, Nevada. "Tell you what, he's really moving," Jimmy Leeward murmurs. Leeward ought to know; he's racing his own P-51D Mustang and L-39 jet this weekend. But he sounds almost reverent when he adds, "He's doing over 300, I'd say."

Sixty-seven years ago to the day, on September 13, 1935, Howard Hughes set a three-kilometer speed record of 352 mph in the revolutionary one-off known as the H-1, 1B, or—his preference—simply the Racer. Five years ago, Jim Wright undertook a project of meticulous craftsmanship crossed with magnificent obsession to re-create the Racer by reverse-engineering the original, which resides in the Smithsonian's National Air and Space Museum. Shortly before seven this morning, Wright wedged his lanky frame into the cockpit of his gleaming replica and took off in search of a world record. Not, mind you, Hughes' record. "Howard was willing to blow his engine up," Wright had explained. But because Hughes set only the unlimited record, Wright can establish a new mark in the Fédération Aéronutique Internationale's 3,858- to 6,614-pound class if he averages better than 266 mph during four consecutive runs.

The radios of the observers manning the record course crackle to life with

Enter, stage left: Jim Wright's pristine reproduction of Howard Hughes' H-1 Racer made its debut at the Reno Air Races in Nevada last September.

MARK JOHNSTON

Both Wright and Hughes made their money from tool companies, and both were bewitched by the sleek design of the H-1.

CHAD SLATTERY

news from the tower: "All stations copy. The Hughes Racer is northbound. Final pass." The airplane swoops down and powers past the start-finish pylon. On the edge of the ramp, three men dressed just like Wright—white button-down shirts and black pants—pound each other on the back. "We done it!" Dave Payne shouts. "We built that airplane!" His eyes follow the Racer as Wright peels off to the west. "We built that airplane," he repeats softly.

A lot of prop-heads will tell you that the Hughes Racer is the most beautiful airplane ever built. Nobly proportioned and gracefully streamlined, the H-1 presaged the engineering of the 1940s while embodying the hand-built virtues of the '30s. Wright estimates that it took 35,000 hours to create his replica, despite the liberal use of computer-aided design (CAD) and computer-numeric-control (CNC) precision machining mills. What he ended up with is the world's most elegant and most ambitious homebuilt. That's right, homebuilt. Sure, some of the work was

California Dreamin'

"Would you like to see the Howard Hughes H-1 Racer?" I asked the Air Force pilot. I was sure "Joe Bill" Dryden would be interested. "Howard set a world speed record of 352 miles per hour in 1935," I added.

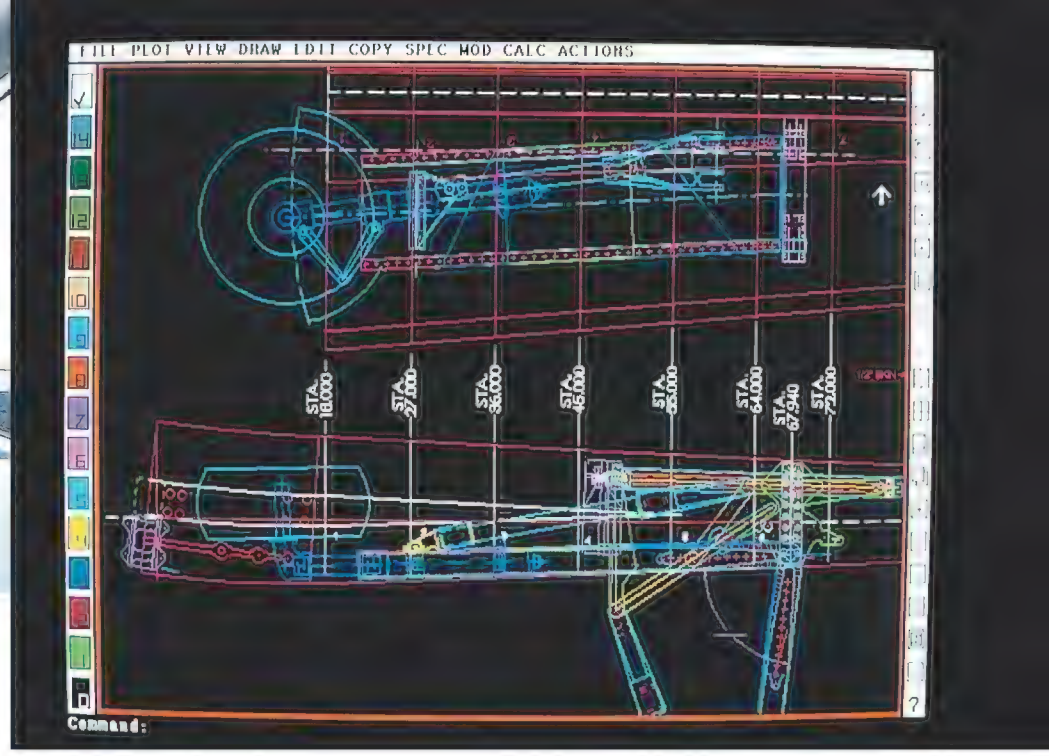
It was the spring of 1975. I was a test pilot for the Hughes Aircraft Company, flying out of the company's private airfield at Culver City, California. Dryden would evaluate our new radar by flying test missions in an F-4 Phantom. I would fly a T-33 target aircraft. We would be spending a lot of time together.

Another Hughes employee, Bruce Burk, the caretaker of all of Howard Hughes' stored aircraft, held the keys to a Quonset hut next to our flight test building. He agreed to meet us there and unlock the door. We could get a peek at the H-1 if we brought a flashlight.

The ghost-like Racer, covered by a canvas tarp, sat behind a locked chain link fence. The vertical stabilizer was exposed and the twin-blade propeller had a blanket wrapped around it. Off to the left, leaning against a wall, was the Racer's second set of wings.

Pilots always look inside the cockpit of an airplane first. We lifted the tarp and stepped under it as you would a tent. The cockpit was smaller than that of the F-4. The canopy consisted of two sections that slid down into the fuselage on each side like the windows of a car. The windscreen could be cranked forward 12 inches so that the seat could move up and forward. This allowed Hughes to see over the nose during takeoff and landing.

Attached to the side of the cockpit was a black leather tool kit containing a screwdriver, crescent wrench, pliers, and an assortment of light bulbs and screws. We didn't see a map case. "Howard didn't use maps," Burk said. "He didn't plot a course or plan his flights very well. He just took off and headed



The team finishes up the landing gear. Members made design drawings from scratch and translated them into computer-aided design (CAD) graphics (right).

farmed out to professional subcontractors. But the vast majority was done in Wright's hangar in Cottage Grove, Oregon, by a crew consisting of three volunteers, a paid employee, and Wright himself. "[Project manager] Ron Englund and I did all the rivets—20,000 of them," Wright recalls. "We got pretty good at it. Pretty fast too."

You'll have to forgive Wright his fanatical devotion. He came up with the idea of building the racer way back in 1978, when he read a reprint of an article, "A Movie Magnate's Racer," published in *Popular Aviation* in 1937. A machinist by trade—his company, Wright Machine Tool, builds industrial saw blade sharpeners—he developed a profound professional appreciation for the quality of the H-1's fabrication and the brilliance of its engineering. But what really sold him on the Racer were the circumstances underlying its creation.

"It was the last non-military plane to set a world speed record," Wright says. "It was also the last time an individual could design an airplane that was world-class. After this, planes of this caliber were designed by teams of hundreds or thousands of people. The Hughes Racer was a personal statement. And when you work on a machine designed by an individual, you learn a lot about that person. The Racer turned out to be a very mysterious airplane. But then, Howard was a very mysterious person."

Wright has spent so much time changing in the general direction of his destination."

The Racer had gently curving wing fillets between the wing and the fuselage to help stabilize airflow, reduce drag, and prevent potentially dangerous eddying and tail buffeting. Even under the tarp I could see that the airplane had graceful curves. On the other hand, the Phantom, with upturned wingtips and stabilizers slanted down, needed brute force to push it through the air. "The F-4 looks like someone had shut the hangar door on it," Burk said. Dryden and I would have eagerly traded our radar test flights in the Phantom to fly the Racer.

In preparation for sending the Racer to the Smithsonian's National Air and Space Museum in Washington, D.C., Howard Hughes wanted the H-1 restored to mint condition by July 1, 1976, when the museum would open. The Racer was in good shape—it had been stored in the Quonset hut, which was rarely opened, for most of its life. Burk towed the Racer across a road to the flightline. To prevent exposure to sun, wind, and rain, it was placed in a 20-foot-high, three-sided wooden enclosure.

Before the airplane could be restored, the wing and fuselage needed to be separated. Because Hughes had not planned to put the Racer into production, Burk had no drawings or schematics—only something called layout forms, which were not very detailed. "The Racer was never meant to come apart," Burk said. It would have to be cut up.

There was no fuel gauge in the original's cockpit. Fuel ran through plastic tubing that wrapped around the panel; when the tubing was empty, the tank was dry.

I made sure to stop and see the airplane and talk to Burk every time I went out to fly. Was he in contact with Howard Hughes? Was Hughes concerned about the Racer? Would he want to see it after it was restored?

"Hughes' physical condition is not good," Burk reported, "but I keep him aware of the Racer's status."

On a Friday afternoon in the late fall of 1975, 40 years after Hughes set the world speed record, the Racer was ready for its long trip to Washington. The fuselage and the wings were packed in large wooden boxes, which were then placed on the flatbed trailers of two trucks. It was sad to watch the trucks depart eastbound; a chapter in the history of the Hughes Aircraft Company had come to an end.

—George J. Marrett

TOP: ROBBIE MCCLARAN (2); BOTTOM: ERIC LONG


N2589Y

neling Hughes that he refers to him by first name, as if they were old buddies. But despite the fact that both men made their fortunes from tool companies, they could hardly be more different.

Howard Hughes is remembered as America's most prominent super-rich weirdo. But in his heyday, he was a dynamic entrepreneur who achieved considerable success in aviation.

Wright, 53, is a hands-on, straight-up, small-town boy partial to western shirts and cowboy boots. He's soft-spoken and open with strangers. It's hard not to be charmed by his enthusiasm for the Racer and his pleasure in others' delight in it. "Jim's fundamental energy," says Kent White, who worked on the project, "is joy."

Howard Hughes, by contrast, is remembered as America's most prominent super-rich weirdo. But in his heyday, he was an entrepreneur who achieved considerable success in aviation, most notably owning Transcontinental and Western Air and sponsoring development of the Lockheed Constellation. Still, the Racer may well be his greatest accomplishment. Designed by Dick Palmer to Hughes' general specifications and built by a small team led by Glenn Odekirk, the H-1 broke the world speed record by 38 mph in 1935. Two years later, fitted with longer wings and bigger fuel tanks, the Racer carried Hughes from Burbank, California, to New York City at an average speed of 332 mph, shattering the old transcontinental record—held, incidentally, by Hughes himself—by nearly two hours.

Hughes' creation was a melange of old and new—wooden wings, fabric-covered control surfaces and tail skid co-existing with an all-metal flush-riveted monocoque, drooping ailerons (which act as flaps at low speed), split flaps, a fire-suppression system, and hydraulically operated landing gear. Conceptually, it harkened back to the time-honored formula of shoehorning a big engine in a small airframe. But thanks to substantial wind tunnel testing and the latest in aerodynamic refinement, the 1B wasn't, like the Granville brothers' Gee Bee, a misshapen bulldog but rather a sleek greyhound whose most prominent feature was the bell-shaped cowl shrouding its twin-row, 14-cylinder R-1535 Pratt & Whitney.

"When we went into this project," Wright says, "we thought the airplane was a racer. It's not. It's a technology test bed. Howard was looking ahead further than a world record. He was building Hughes Research Number One. He was building the team that would eventually put satellites into orbit. He was building a company, not just a racer."

In the spring of 1998, Wright and his wife, Betty, decided they had the time and the resources—CNC mills among them—to build a replica. But Wright couldn't undertake the project until he secured an exceedingly rare Twin Wasp Junior. Miraculously, his first call, to California motor man Millard Marvin, hit paydirt. "We thought they were falling off trucks!" Wright jokes. "Then we spent the next three weeks calling everybody across the country [to see what was out there], and we couldn't find another one." Marvin also had an old Grumman Albatross propeller that could be reshaped to fit the Racer's specifications. Meanwhile, Marvin's engine was

The original racer had two sets of wings: short, for dashes, and longer, for distance. For his reproduction, Wright commissioned the long wing.

Left: A glimpse inside the fuseslage as it tapers toward the tail. Below: Ron Englund sets sheet metal fasteners on a landing gear "grass cutter. Right: the cutter in place.

OPPOSITE PAGE AND BELOW: CHAD SLATTERY; MIDDLE: ROBBIE MCCLARAN (2)

Fresh from Steve Wolf's shop, the wing arrives at Wright's hangar (left). In the hangar, Wright covered one wall with a head-on image of the team's goal, one that shows off the wing's dihedral (upward angle).

DENNIS PARKER (2)

sent to Tulsa Aircraft Engines in Oklahoma for a rebuild.

In putting together a team to build the airplane, Wright didn't stray far from his home in Cottage Grove, a small logging town an hour south of Eugene. His old friend Mike Mann, a retired logging contractor whose father had owned and operated a small airport, came on board as a full-time volunteer. So did Dave Payne, an aircraft mechanic who used to maintain Wright's other aircraft (a Beech Bonanza, a Taylorcraft, and a Glasair III), and Al Sherman, a retired trucker with three homebuilts to his credit. To oversee the project, Wright hired Ron Englund, who shares his placid demeanor. Although Englund was the youngster of the bunch—a mere 35 at the time—he'd already restored several antique airplanes.

Wright had a team. What he didn't have was an engineering plan. An exhaustive search turned up not a single schematic, blueprint, or wing planform. To date, in fact, he's located only a handful of photos of the Racer under construction (including just one shot of the uncovered wing), and the last remaining member of the original design team, John Newberry, died while the replica was being built. Fortunately, Hughes had donated his racer to the National Air and Space Museum, and museum officials Robert van der Linden and Bill Reese agreed to allow Wright to measure, photograph, and examine the original inch by inch.

When they first confronted the H-1 in person, they were struck dumb. Not with awe but with dread. "It was heartbreaking," Englund recalls. "The plane was so nice. To come anywhere close to that standard of quality—well, we knew it was going to be very tough."

To prepare for the pilgrimages his team would make to the Smithsonian, Wright enlarged the scale-model plans drawn by aviation historian Paul R. Matt. From there he fashioned a full-size mockup of plywood. Studying it, the team came up with hundreds of technical questions: How long was that spar? How thick was this piece of metal? How did the landing gear work? In short, how did the mockup compare with the original? ("Ninety-five percent was dead-on," Wright says, "but that five percent would have killed us.")

Wright commissioned Steve Wolf to build the wings—the long ones used to set the cross-country record, rather than the clipped set used for Hughes' speed runs. Wolf, who lives in the neighboring town of Creswell, was best known for creating the Gee Bee replica owned and flown by airshow performer Delmar Benjamin. In June 1998, Wolf and his wife Liz traveled to Washington, D.C., for a look at the Racer. Using a pair of home-made four-foot calipers, they took the necessary measurements and returned to Oregon convinced that the wings were buildable.

A few months later, Jim and Betty Wright went to Washington with Ron Englund. When they first confronted the real H-1, they were struck dumb. Not with awe but with dread. "It was heartbreaking," Englund recalls. "The plane was so nice. To come anywhere close to that standard of quality—well, we knew it was going to be very tough." Englund had planned to determine the thickness of the aluminum skins that form the surface of the fuselage by inserting a feeler gauge into the gaps where they butted up against each other. But the H-1 had been put together with such impeccable craftsmanship that there were no gaps. None. Zero. "That was the low point," Wright says. "We realized then that we were fighting a real battle, and we needed the best soldiers."

Back in Cottage Grove, Wright Tool employees Guy Ralstin and Dennis Parker generated more than 1,000 CAD drawings while Wright and his hangar crew fabricated most of the fuselage, bending the aluminum skins, riveting them in place, countersinking the rivets, then sanding and polishing the surface until it was smooth and unbroken. But the more elaborate pieces demanded special handling. The fiendishly complex curves of the engine cowl, for example, were shaped by Jim Younkin of Springdale, Arkansas, a restorer and replica builder who spent

Dave Payne at the daily grind: more work on the landing gear. Wright's Racer got a tailwheel instead of a tailskid to avoid gouging runways.

an entire year on the project. "The sheet metal cost more than a new Corvette," Wright says. (The entire airplane, he says, ran more than $1 million.) There's also a tail section so artfully crafted by Kent White of Nevada City, California, that it deserves its own museum exhibit. "I usually get things right the first time," says White, who cut his teeth restoring exotic cars. "If not the first time, then the second. This tail section, I threw away three pieces—three!—before I got it right."

The wings too are works of art, and ran up 3,000 hours on Wolf's clock—half as long as it took to build the entire Gee Bee replica. Hughes chose wood because it could produce a smoother surface than metal. Wolf used light-colored sitka spruce for the spars and ribs, and he covered them with dark mahogany plywood. A fiberglass fabric the thickness of a nylon stocking was stretched across the wing skin, and epoxy was squeegee'd into it. When the glue dried, it was block-sanded until, as Wolf puts it, "you could put a six-foot straight-edge across the wing and not have a piece of paper go through it." The finishing touch was 13 coats of polyurethane paint, which give the wings a dark blue liquid luster.

Although the replica is a visual twin of the original, there are differences between them. Look closely at Wright's airplane and you'll see modern wheels, tires, and brakes, for safety's sake, as well as a tail wheel instead of a tail skid to prevent gouging runways. Some

TOP: ROBBIE MCCLARAN; BOTTOM: CHAD SLATTERY

The price of perfection? For the replica, about $1 million and 35,000 hours.

pieces, like the horizontal stabilizer, are the product of informed speculation. "The only clue we had as to how it was made was the number of screws," Englund says. Wright also replaced some forgings—most prominently in the landing gear—with stronger pieces CNC'ed out of aluminum billet and sandblasted for a period look. Safety also inspired him to use rubber-bladder fuel cells instead of welded-aluminum fuel tanks, halon rather than carbon dioxide (or carbon tetrachloride, nobody's sure which) in the fire suppression system, and, to reduce the possibility of flutter, pushrods, rather than cables, to actuate the ailerons.

When he leveled off, the propeller remained stuck in low pitch, which gave him a paltry 120 mph at the engine's 2,625-rpm redline. As the engine temperatures rose, Wright quickly reviewed his options for an emergency landing.

Just how close the re-creation came to the original became disconcertingly apparent when the Racer first flew in July. As Wright sat in the cockpit, idling on the short runway outside his hangar, he took a deep breath. Although the airplane had performed flawlessly during extensive taxi tests, Wright says "there was always the nagging fear that the reason Howard flew [the H-1] only 42 hours was because there was some serious problem, which he never would have said anything about.

CAROLINE SHEEN

On display at the Reno Air Races, the rule was "look, but don't touch." And best wear sunglasses, lest the highly polished aluminum skin sear your retinas.

Was there a bear trap waiting for us?"

Wright lifted off in a level attitude at about 115 mph. The airplane exhibited benign flying qualities as it climbed. But when Wright leveled off at 5,000 feet, the propeller remained stuck in the low-pitch setting, limiting him to a paltry 120 mph at the engine's 2,625-rpm redline. As the engine temperatures rose, Wright quickly reviewed his options for an emergency landing. Fortunately, the temperatures stabilized, and he was able to set the airplane down in Corvallis, as planned.

Notwithstanding the champagne celebration that followed, it was clear that something was amiss. Wright knew from his research that the propeller had misbehaved during Hughes' first flight too. After poring over before-and-after photos of the original airplane, Wright and his team realized that Hughes had retrofitted a bigger counterweight to the propeller. Since the counterweight enables the prop to shift into high pitch, the team surmised that Hughes must have run into the same problem that Wright did 67 years later. A larger counterweight was mounted on the replica, allowing the airplane to take full advantage of 700 horsepower.

Wright made 19 more takeoffs and landings during his flight test program. Aside from an abrupt stall characteristic and poor visibility on approach, the airplane was so stable that Wright says it could be flown with no trouble by a low-time pilot. By the time Wright made the 65-minute hop from Cottage Grove to Stead Field in Reno—cruising at 295 mph, 50 percent power, and 10,000 feet—the replica had accumulated more flight time than the Racer logged in its entire career.

The speed record attempt in Reno was just the means to an end: giving the Racer replica an appropriately grand debut. Wright shattered the old mark with an average speed of 304 mph. But back on the ground, after accepting the congratulations of his crew and hundreds of well-wishers, he quietly confides, "We've still got some issues to deal with." A lingering pitch problem limited Wright to 62 percent power, and the leather seal in the prop took such a beating that grease flowed into the airstream and slathered the canopy. "Visibility was so bad I couldn't have done one more run," he says.

In January, the right landing gear collapsed on rollout. The damage is being repaired, and Wright hopes to replicate Hughes' record-setting cross-country flight. He also plans to take his airplane on the airshow circuit. As it is, the Racer is the star attraction where it's parked on the ramp in Reno. In fact, hardly anybody seems to notice the rare P-63 Kingcobra or F7F Tigercat on either side of it.

Later, after most of the spectators have left, a passerby spies the unguarded Racer. "Major wow!" he says. After a furtive look around, he ducks under the protective rope and reverently strokes the fuselage. A security guard materializes and orders him to get out of there, pronto. "Sorry," the interloper says sheepishly. "I couldn't resist."

The two of them stand there for a moment, gazing at the airplane. "It's like a beautiful woman, isn't it?" the guard says.

"Yeah," the interloper agrees. "Like a beautiful woman."

NASM DISC #1B07335

In 1937, after breaking his transcontinental record with an average speed of 332 mph, Hughes taxied triumphantly at Newark Airport in New Jersey.

BACKGROUNDER

What's a Scud?

by Bruce Berkowitz

The Scud missiles causing so much anxiety in the world today are Soviet designs that originated in a weapon developed by the Nazis.

"Scud" is a Western term. The names of Soviet weapons we're familiar with came from the Air Standards Coordinating Committee, a military group founded in 1948 by the United States, Great Britain, Canada, Australia, and New Zealand. The committee gave surface-to-surface missiles names starting with "S"—Shyster, Sandal, Skean, etc. The North Atlantic Treaty Organization later adopted the naming conventions, as did the Soviets, who were so secretive that they would often use the Western terms rather than utter the forbidden Russian names.

During the cold war, NATO used "Scud" to refer to a specific missile, the R-11, a Soviet theater-range weapon intended to strike targets in Western Europe. Scuds were manufactured by the Votkinsk Machine Building Plant from 1959 to 1984. Today, however, "Scud" is like "Kleenex" and "Xerox," brand names that are used to refer, generically, to all similar products. In this case, the product is any single-stage, storable-propellant military rocket with a range of between 186 and 372 miles.

Scuds are often described as Soviet modernizations of the V-2, a surface-to-surface rocket that the Germans built during World War II. In fact, the Scud family was derived from a relative of the V-2, the *Wasserfall*, a radio-directed anti-aircraft missile that rocket pioneer Wernher von Braun and his team first tested in the German town of Peenemünde in 1944. Olaf Przybilski of the Technical University of Dresden discovered this link a few years ago when he interviewed German rocket engineers that the Soviets had conscripted to work for them after the war.

What distinguished the Wasserfall from similar weapons was its oxidizer: nitric acid. Unlike liquid oxygen, the oxidizer used by the V-2, nitric acid can be stored at normal temperatures inside a rocket for long periods—essential for an anti-aircraft missile, which needs to be ready to fire on a moment's notice. In the late 1940s, the Soviet air defense force cloned the Wasserfall and called its version the R-101. The Soviet army soon realized storable propellants offered the same benefit, shorter prep time for launch, for surface-to-surface missiles. Soon engineers drew on the R-101 to design the R-11 ballistic missile—the Scud. The die was cast.

A few years later, the Soviets designed a successor to the R-11, the R-17. With a more powerful motor and more potent propellants, it had more than twice the range (186 miles versus 80). Western military services did not know the R-17 was really a new design so they called it the Scud-B. During the 1960s and 1970s, the Soviets exported Scud-Bs, which were often an inexpensive substitute for an air force, to their Warsaw Pact allies and to clients in the developing world. South Yemen was one example. The Scud-B's extended range gave South Yemen the ability to hit Sanaa, capital of North Yemen, its perennial rival.

AP/WIDE WORLD PHOTOS

IN BRIEF: SCUDS

- During the 1991 Gulf War, a Scud attack on a barracks in Saudi Arabia killed 28 U.S. military personnel and injured 100 more.
- In a move to eliminate Iraq's Scud arsenal, the cease fire ending the Gulf War limited Iraq to missiles with ranges of less than 93 miles.
- In addition to carrying warheads containing high explosives, Scuds could be modified to deliver biological, chemical, or nuclear payloads.

The R-17 not only became the most proliferated ballistic missile in history, it also inspired more derivative designs than any other. But even today, Wasserfall DNA appears in the Scud and in all of its progeny: They all have the same 35-inch diameter as the original.

The event that spread Scud technology around the world was the 1973 Israel-Egypt Yom Kippur War. As a sign of socialist solidarity, North Korea sent a few pilots to Egypt. After the war, Egyptian officials hoped its new Korean friends would get into the business of manufacturing replacement parts for the Egyptian army. (Egypt was equipped mainly with weapons from the Soviet Union, but relations between the two governments had soured.) So in 1976, Egypt shipped a few Scud-Bs to North Korea. The North Koreans reverse-engineered the missiles, and by the 1980s they were ready to build their own. It was largely this Egyptian-Korean connection that spawned the many Scud variants we see today.

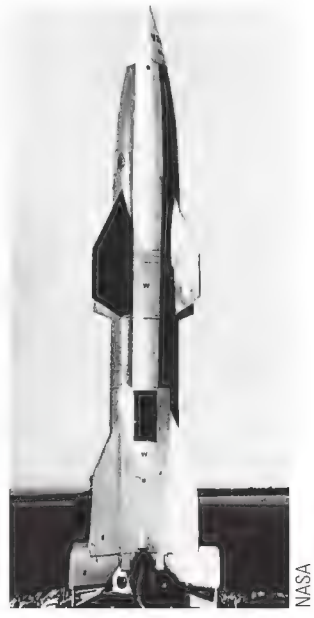
Western analysts called the Korean R-17 copy the Hwasong-5. Officials in Pyongyang quickly realized that sales of R-17 knock-offs might bring in badly needed hard currency. (Indeed, it was a derivative of the Hwasong-5 that the Spanish navy discovered on a North Korean freighter headed for Yemen last December.) North Korea found a ready customer in Iran, which in the 1980s was in the middle of a no-holds-barred war with Iraq. At this point, the R-17's genealogy began to double back on itself. The Iraqis, as it happened, had their own Soviet-supplied Scud-Bs. After the Iranians hit Baghdad with a few dozen Hwasong-5s, the Iraqis wanted to retaliate. The Iranian city of Tehran, though, was much farther from the border than Baghdad. The Iraqis' solution was to extend the range of their Scud-Bs by splicing additional sections into the propellant tanks and using a smaller (and therefore lighter) warhead. Iraq, whose leader apparently couldn't miss a chance for self-promotion, dubbed the missile al-Hussein. It could deliver a one-ton warhead 370 miles, just far enough to reach the Iranian capital. During the winter of 1988, the two countries fired missiles at each other in what became known as the War of the Cities.

All Scud-derived missiles are mainly terror weapons. Because their gyros and electronics date back to the 1950s, the missiles are notoriously inaccurate. The original R-17 had a circular error probable (CEP) of about 3,300 feet, meaning that half the missiles aimed at a target would land more than two-thirds of a mile away. This never mattered to the Soviets; since they planned to arm the missiles with nuclear or chemical warheads, most targets would still be in the lethal zone. Other countries used the imprecise Scud as a crude device for lobbing a ton or two of high explosives somewhere into an opponent's cities. In 1988 Iraq fired about 500 al-Husseins at Tehran, killing 1,000 to 2,000 people.

Yet the greater threat of Scuds has always been not what they are today, but what they can lead to tomorrow. After the War of the Cities, the North Koreans took a cue from the Iraqis and began a project to build a Scud derivative that was 50 percent bigger in each dimension. Western analysts labeled the rocket the No Dong (as with all North Korean rockets, the analysts simply named the missile after the town near where it was first spotted). Because the No Dong can hurl a one-ton warhead 930 miles, it can reach any part of South Korea and Japan.

Pyongyang has exported No Dong missiles, components, and technology to Pakistan (where it is called the Ghauri 2) and Iran (the Shahab 3). North Korea reportedly is also developing missiles that combine No Dong and Hwasong components into multi-stage rockets. These missiles, the Taepo Dong series, could reach Alaska, Hawaii, and even parts of the continental United States.

It's easy to make light of missile programs in North Korea, Iran, Iraq, and other developing countries. Compared to our own, they seem primitive. But each country is really just going through the steps Soviet designers followed 50 years ago: using borrowed technology, making gradual improvements, and combining smaller rockets into bigger, longer-range rockets. And so it's only a matter of time—probably less rather than more—before these countries, left to themselves, will be able to build truly threatening weapons.



NASA

Opposite: A North Korean Scud-B towers over missiles at the War Memorial Museum in Seoul, South Korea. Right: The Scud's progenitor, the Wasserfall.

THE HUNT FOR EXTRASOLAR EARTHS WILL OWE MUCH TO ONE MAN'S METHODS, AND HIS UNEARTHLY TENACITY.

Bill Borucki's Planet Search

It should have been a moment of triumph: the maverick prophet finally welcomed into the high temple. After 20 years of dogged and often lonely effort bordering on obsession, Bill Borucki had won approval from NASA to build the first spacecraft designed to find Earth-size planets beyond our solar system. If successful, his mission, named for Johannes Kepler, the astronomer who calculated laws of planetary motion, could rewrite our understanding of solar system formation and single out targets in the search for extraterrestrial civilizations.

But in January 2002, just weeks after the mission's approval, Borucki's legendary patience was tested by a meeting held with officials in a windowless room at NASA's Washington, D.C. headquarters. Agency managers first offered congratulations, only to sheepishly explain they were short on cash and had to delay the project's launch by a year, to 2007. What's more, the team would have to turn control of the project over to a rival NASA center. When Borucki informed his colleagues—a close-knit mix of seasoned space veterans and eager postdocs—they were astonished, then furious. "People turned colors," Borucki recalls with a smile.

After living in the wilderness for so long, Borucki was not about to let small matters such as money or management derail his project. While others on his team continued to rant and fume, Borucki quietly returned to his office at NASA's Ames Research Center, south of San Francisco, and set about doing what the agency hierarchy requested.

"All I care about is the science," he says one evening over Chinese food. Coming from most scientists, the statement would sound naive or simply platitudinous, but Borucki leans his spare frame forward, and this time he doesn't smile. "And when I go home tonight," he says, "I will work."

Counting Photons

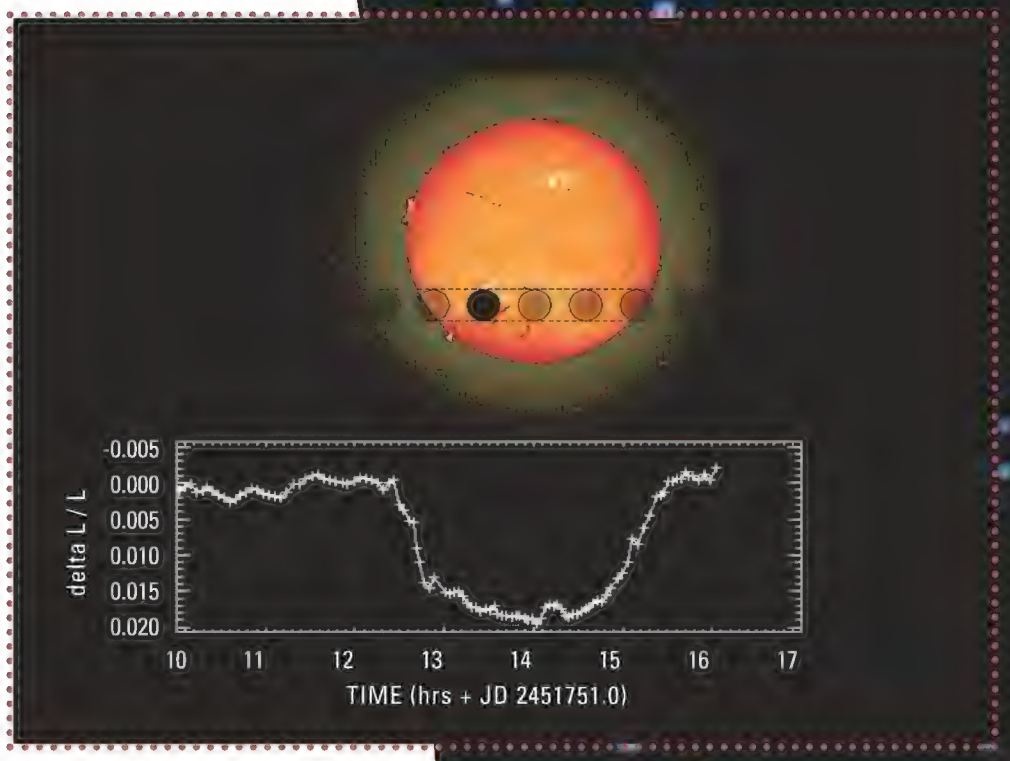
The search for extrasolar planets is one of the most spirited pursuits in modern as-

tronomy, with potential Nobel Prizes driving physicists as forcefully as innate curiosity. Since a Swiss team located a giant planet in the constellation Pegasus in 1995, researchers have racked up around 100 planetary systems and many more candidates. The race now is to find Earth-size planets; the holy grail is to find one in the habitable zone, where temperatures would allow liquid water—and therefore possibly life—to exist.

The standard method for planet searching, astrometry, involves looking for a regular wobble in the parent star—a sign of its brood's gravitational tug—but the worlds discovered by this technique are typically larger than Jupiter and often orbit as close to their stars as Mercury does to the sun. Though important for the impact they've had on solar system formation theories, the planets are hardly Earth-like. With current technology, astrometry is also limited; at best it can spot terrestrial planets only around the nearest stars. And enormous practical challenges involving precision flying and mirror technology still have to be solved before interferometry and coronagraphy, conventional ground-based approaches, will work from a platform in space.

To find smaller planets at greater distances, other methods are needed; it's here that Borucki is cutting a new path. His small and relatively simple spacecraft, Kepler, will employ a revolutionary technique called transit photometry, which precisely counts photons from a star's light to detect periodic dips. Kepler will fix its eye on 100,000 stars in the constellation Cygnus, and during a four-year mission around our sun it will stare relentlessly at those stars for dimming, which could mean planets are passing over the faces of—transiting—their home suns. Three dips of the same duration and degree and at equal intervals would confirm an orbiting entity.

Cygnus, lying 55 degrees above the solar system's ecliptic plane, is a particularly good target; it's home to a dense star field and can't be obscured by asteroids or sunshine. Borucki's team will study around 135,000 of the constellation's dwarfs—those similar to our sun—and after a year weed out roughly 25 percent that are too variable for transit spotting. Before budget issues and hardware reliability come into play, Kepler will have the opportunity to see up to four transits by planets in one-year orbits and up to three by those in 1.9-year orbits.



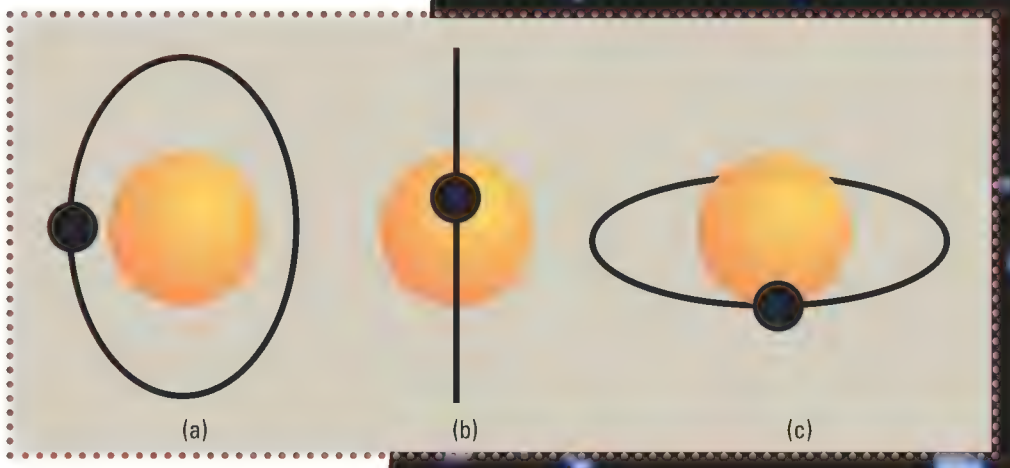
Sweat and Zeal

Borucki's single-minded zeal is as clear as his youthful blue eyes. Born in Chicago in 1939, he grew up in Delavan, Wisconsin, "between Yerkes Observatory and the Playboy Club on Lake Geneva," and expressed interest in astronomical matters early on. While in his teens, the town sheriff would close off roads so that Borucki and his buddies could launch 10-foot multi-stage rockets. Borucki's father, an inspector at a clock factory, procured timing mechanisms for them.

In 1962, a year after President Kennedy challenged the Soviets to a moon race, Borucki, fresh from a physics degree at the University of Wisconsin at Madison, landed at Ames, where he studied the effects of radiation on reentry vehicles—work that was used to design Apollo heat shields. But what ultimately fired his passion was the possibility of discovering other worlds.

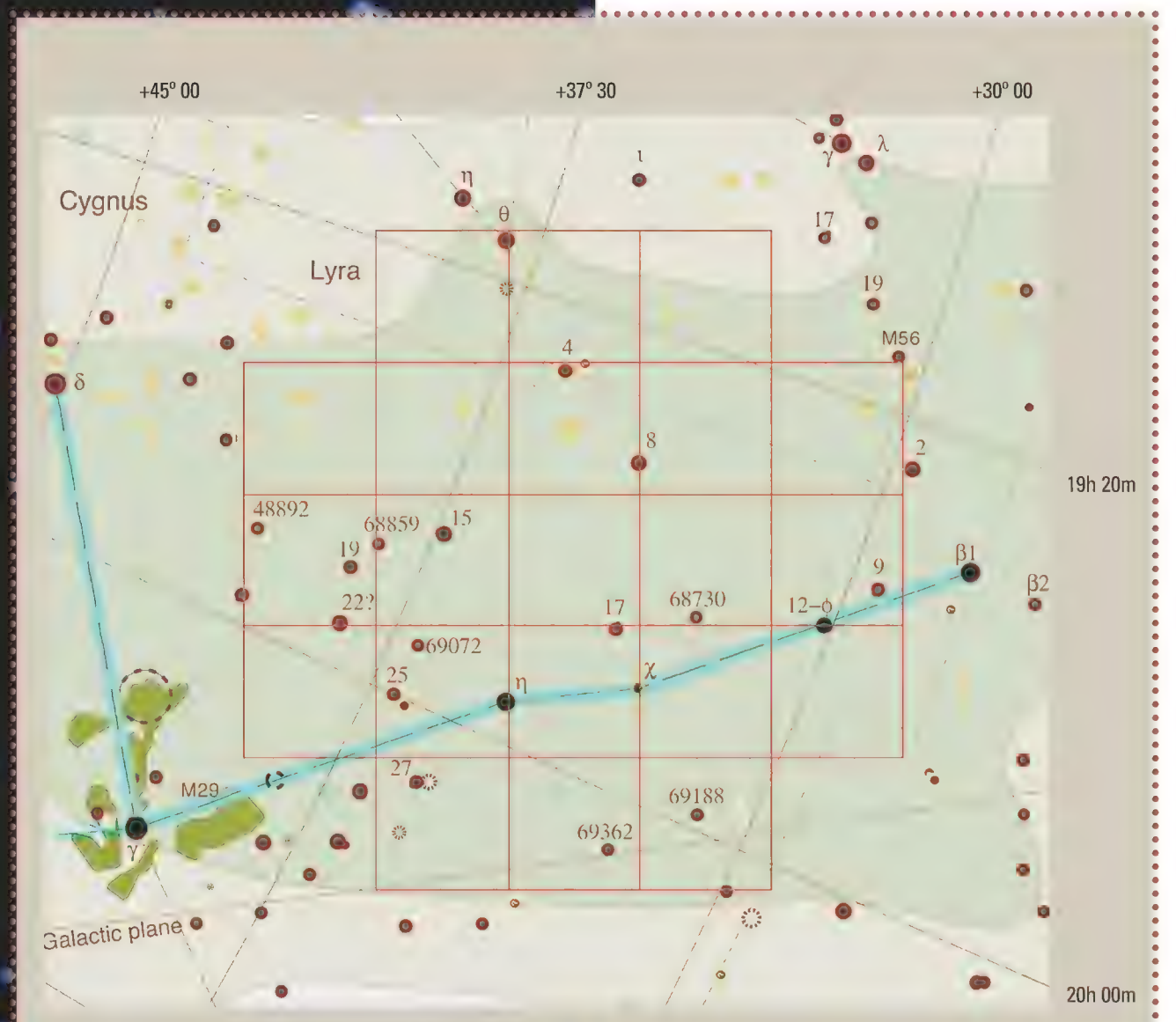
He was in the right place. In the 1970s Ames hosted a session on space colonization, and it also was the home of NASA's Search for Extraterrestrial Intelligence. Borucki got to know many of SETI's legendary figures, including Carl Sagan and Jill Tarter.

In the summer of 1982, Borucki looked in on an Ames conference on extrasolar planets, a far-out topic at the time. Transit photometry was mentioned only in passing because detectors of



Top: A U-shaped dip in a star's brightness is the telltale sign of a transit. Right: Each of the five-square-degree fields in Cygnus to be monitored by Kepler's 21 charge-coupled device pairings. Below: Transit scenarios. Kepler will see (a) no dip in starlight when a planet's orbital plane is perpendicular to its line of sight; (b) a long, deep dip if a planet transits near the center of a star; (c) a barely discernible dimming if a planet passes over just a sliver of its home sun.

TOP: INSTITUTO DE ASTROFISICA DE CANARIAS; RIGHT: DR. DAVID KOCH, NASA AMES RESEARCH CENTER



"He's shown [with Vulcan] that he can find eclipsing binaries, which are as hard to find as looking for transits."

the day simply couldn't measure stellar variability to the degree necessary. "We needed precision of one or two parts in a hundred thousand, and no one knew how to get there," he recalls.

The idea of transit photometry wasn't new. Astronomer Frank Rosenblatt speculated in a 1971 paper that the method could prove a valuable tool, but he died shortly thereafter. Borucki picked up the thread and became increasingly intrigued—some would say infatuated—with the possibilities. He published a couple of papers on the subject, and in 1984, he somehow persuaded the director of Ames to fork over enough money from his discretionary purse to fund a small conference on the subject.

Roughly 20 astronomers attended the meeting, held in San Diego, and decided that it was theoretically possible to build such detectors. Scientists at the federal National Bureau of Standards suggested silicon diodes as quantum-perfect detectors—devices that would spit out a single electron for every photon of light absorbed. For three years Ames' director used his discretionary fund to pay for Borucki's development of silicon diode detectors, but Ames managers questioned how well the detectors would operate in space and remained skeptical.

In the late 1980s, Borucki's team began to look at charge-coupled devices—technology more familiar to the astronomical community. Unlike silicon diodes, which can monitor only one star at a time, CCDs are array detectors that can survey thousands of stars simultaneously and are ideal for digital data gathering. Borucki had tested CCDs years before and had been disappointed with their degree of precision, but his team determined that newer CCDs were capable of the precision necessary to detect minuscule brightness changes. Though they'd never be as precise as silicon diodes, Borucki chose to go with CCDs for credibility.

"I hate CCDs," he says, chuckling but serious. "The only reason I chose them was because I knew I had to convince the community that we could do the job. It was easier to convince them with CCDs than it was with silicon diodes." His spacecraft would eventually require dozens—the most recent design calls for 42, compared to the Hubble Space Telescope's four.

Here to There

In early 1993, Ames called for a review of Borucki's work. Just as space-qualified CCDs were becoming commercially available, Borucki gave an eight-hour presentation that convinced Ames of his project's feasibility.

New data from NASA's Solar Max mission lent a supporting hand. "Solar variability was coming out to about 10 parts per million. At the time scale of a transit, solar variability is much smaller than a transit," says Dave Koch, Kepler's deputy principal investigator and Borucki's right-hand man. "The [review] committee said 'Yes, this can now be done. It's not just a cute idea, it really is a practical idea.' "

From then on, the center quietly provided a steady stream of money for the project. Ames officials backed the high-risk research for its own sake, but they were also aware of the interferometer

work being done by their NASA rivals at the Jet Propulsion Laboratory in Pasadena, and entering the planet race appealed to their competitive instincts.

By 1994, Borucki and his team had closed in on the algorithms necessary to make sense of CCD data, and the project, nicknamed FRESIP (Frequency of Earth-Sized Inner Planets), was ready to compete for a NASA Discovery mission. (Discovery missions were to reflect NASA chief Dan Goldin's vision of cheaper and more tightly focused projects that could be launched 36 months from selection and cost no more than $299 million from design through launch and data analysis.)

Though NASA liked the concept of FRESIP, it was shot down by reviewers, who said the effort would cost far more than the team anticipated. Several team members believed NASA overestimated costs by simply scaling down the expenses of bigger, more inherently complex missions. "We were put in the same box as the large high-precision astronomical telescopes," says Larry Webster, Kepler's project manager and an old NASA hand who has worked closely with Borucki for the past decade.

Two years later, Borucki and his team were ready again. This time they had three groups check out their costing scheme, but reviewers said that the system, renamed Kepler to distance it from FRESIP's price tag flap, didn't seem capable of imaging the promised tens of thousands of stars. So the team built a camera with a CCD and began testing it in October 1997 at Lick Observatory in the nearby mountains. Lacking funds to hire anyone to operate the device, called Vulcan, Borucki organized a program in which volunteers would take care of the night shifts required to keep Vulcan functioning.

It wasn't too hard to convince people to pitch in. Researchers at SETI were eager for the Kepler team's data so that they could point their giant radio telescopes at systems with Earth-size planets. Astrobiologists at Ames strongly supported the mission too. "We really believed in the potential of the project so we donated our time," says Ames Integrative Studies Lead Lynn Harper. After many treks up to the observatory, Harper and other volunteers managed to find the money to enable Borucki to hire an operator.

Though the tests weren't designed to spot terrestrial planets, other discoveries, later verified by spectroscopy, proved that the remotely operated camera was photometrically precise. "He's shown that he can find eclipsing binaries, which are as hard to find as looking for transits," says Koch.

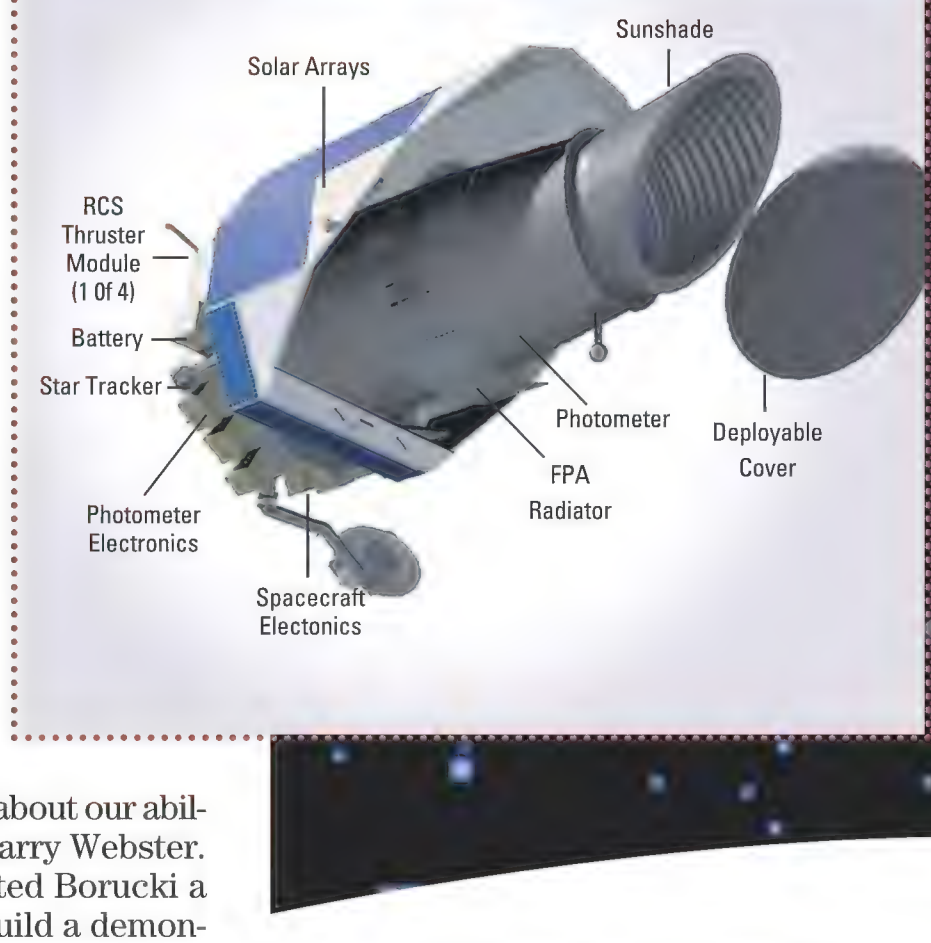
Go Prove It

When the team came back with yet another Discovery proposal in 1998, reviewers complained that in space, cosmic rays or noise and jiggles in the spacecraft could interfere with the precision of the detectors. The Kepler team took it in stride. "They always loved the science [but] they always had a technical question about our ability to do the job," says Larry Webster.

This time NASA granted Borucki a half-million dollars to build a demonstrator that could prove the proposed system would work. It was an unprecedented step for NASA headquarters. Ames agreed to match the amount, and within 88 days—Webster counted them one by one—the team assembled an end-to-end ground system. "We worked seven days a week, and had most of the machine shops in the [San Francisco Bay area] working with us," Borucki says.

The Kepler Tech Demo, a 10-foot phone-booth-like steel-and-styrofoam frame, surrounded a single CCD, a coolant system, and other hardware. It took six months to get it working, and Borucki grew nervous. "We were spending Ames money like crazy," he recalls, "and I was waiting for the moment they would say, 'Hey Bill, great try, why don't you move on to something else?' " The results from the contraption, however, clinched the deal: The Demo detected simulated planetary transits—brightness changes of 100 parts per million—in a mocked-up 1,600-star sky. In December 2001, reviewers ran out of criticisms. Kepler was chosen as a Discovery mission.

Kepler will take notice when planets blot out starlight. Off-the-shelf technology and just one deployable part kept costs low and helped sell the mission to Discovery reviewers.



For Webster, NASA's challenge made all the difference. "It was kind of a 'We don't quite believe you can do it. Go prove it. When you're ready, come back,' " he recalls. "We did that in spades and came back in the 2000 proposal and there was just nothing left to critique. We were perfect."

It wasn't an unalloyed victory, though. Weeks later, following Borucki's meeting with NASA managers, the Kepler team swallowed hard and turned mission development (everything up to launch) over to JPL—one of the two NASA centers, along with the Goddard Space Flight Center, designated to carry out missions beyond Earth orbit.

Nailing the Numbers

With Kepler's selection, Borucki's biggest victory may have been on behalf of Ames in its sibling rivalry. Up

DR. DAVID KOCH, NASA AMES RESEARCH CENTER (2)

to that point, says Kent Cullers, who is in charge of R&D at the now-private SETI, "JPL has had the lion's share of the R&D funding" for finding Earth-like planets.

JPL managers, once critical of the project, now sing Kepler's praises. "Kepler will do a great job nailing down the numbers" of terrestrial planets, predicts Charles Beichman, chief scientist for NASA's Terrestrial Planet Finder program. Its findings may help determine the TPF mission's design. "We've pushed Kepler aggressively in the last four or five years," he adds, though he admits that in "the mists of time," questions were raised about Kepler's efficacy. "Now it is very solid and credible," Beichman says.

Beichman and others are nevertheless quick to point out Kepler's limitations; imaging stars mostly at great distances using photometry, Kepler can find evidence of terrestrial worlds but can't provide more specific characteristics. So while astronomers will learn much about the distribution of such planets, it will be up to later missions to pinpoint what kinds of atmospheres and surfaces such worlds might have—and whether life exists on them.

NASA will seek answers to these questions with its Origins missions, which will include Hubble's successor, the Next Generation Space Telescope; the Space Interferometry Mission, which will search among wobbling stars for planets; and the still-far-off TPF mission, which will attempt to photograph distant planets and study their sizes, positions, and atmospheres.

The Kepler team's greatest challenge will be deciphering the reams of data its spacecraft beams back. Gregory Henry, an astronomer at Tennessee State University, says that the tough part will be differentiating between a small planet and stellar variability, or detecting the existence of a nearby binary that is subtly eclipsing the target star. Small dead suns circling active stars also could fool Kepler. And many small planets won't cross between their sun and the spacecraft.

The way to resolve the problems is by doing intensive ground-based observations to determine with precision the movement of each star, its mass, and its rotation speed to ensure that the dimming effect is in fact caused by a planet. "I see no showstoppers," says Henry, "but it will be difficult to interpret the results." Borucki insists that his scientific team, which includes many astronomers with access to large telescopes, is aware of the interpretation tangles. Cullers says that SETI is already excited to use Kepler's data.

European Competition

If imitation is the sincerest form of flattery, then Kepler should no longer be considered an oddball program run by a maverick. Two ground-based international networks, Transits of Extrasolar Planets and Optical Gravitational Lensing Experiment, have used the transit method to find evidence of planets, though all have been substantially larger than Earth. Last January, OGLE announced the discovery of yet another Jupiter-size planet, this one 5,000 light-years away—the most distant found—with an orbit of just 29 hours and surface temperatures that probably reach 3,000 degrees Fahrenheit.

Borucki is confident there are plenty of smaller, more hospitable worlds in our galaxy, but is mindful that finding extrasolar life is the ultimate goal. "The next step is to go there and join the club of intelligence" or, he believes, if no other terrestrial planets are found, accept the idea that we are likely the lone sentient beings in the Milky Way. "This is like Columbus," he says of Kepler's search. "How much would you pay to be part of that expedition—to be first?"

European researchers are laying plans for two photometric space missions as well. The first, called COROT, would be able to spot only planets 10 times larger than Earth. Its 2004 launch date, however, is in question due to budget troubles. The other mission is a more formidable competitor for Kepler. Dubbed Eddington, after British astrophysicist Arthur Eddington, whose measurements of gravitationally bent starlight confirmed Einstein's general relativity theory, it will also look at Cygnus and study its distant stars for potential terrestrial companions.

Compared to Kepler, Eddington, slated for a 2008 launch, won't last as long or image as many stars, and those involved are quite aware that Borucki's team has a jump on them and an excellent chance of finding planets. However, Europe has excelled in extrasolar planetary detection, and researchers there are loathe to give up the early lead. "The Kepler team has put years of effort into ensuring that all aspects are understood," says Alan Penny, an Eddington team member based at Britain's Rutherford Appleton Laboratory. He warns, however, that launch dates can change—a polite hint that Europe could try to scoop Kepler.

Borucki's affable manner vanishes at the mention of a race. "We will beat the Europeans in any competition," he says forcefully. "We have the expertise and the support." His eyes quickly soften. It is late. And there's no doubt he will be working into the night.

How the 747 Got Its

(and other stories)

Airplanes look the way they do for a reason.

It's just that the reason is not always what you might

by Bill Sweetman Illustrations by

After the Boeing 747 got a hinged door in its nose so it could open wide for cargo, other design considerations shaped its forehead.

Arguing that life evolved without intelligent guidance, say the people who believe in "intelligent design theory," is akin to arguing that a tornado hitting a junkyard could create a Boeing 747. So, I ask them, why does the 747 have an upstairs cabin? Because Boeing planned it that way, they answer. They are quite wrong, but the example of the 747 is useful because it points to some important general rules about how airplanes come to be the way they are.

Behind the scenes at the Farnborough airshow in England in the summer of 2000, Boeing was keen to share its opinion that Airbus' weight numbers for the A380 dual-deck jumbo, which is to enter the fleet in 2006, were optimistic. Retired 747 chief engineer Joe Sutter was there just to remind people that Boeing had studied a dual-deck airplane as long ago as 1965 and had rejected it as too heavy.

Boeing was competing for a supersonic transport contract in 1965, at about the same time the 747 was conceived, and Pan Am founder and chairman Juan Trippe believed that the big subsonic jets would end up as freighters and that the SST would replace the 747 on passenger routes. Trippe was one of Boeing's best customers and usually the first to order new models, so Boeing put the flight deck of the 747 above the passenger cabin to give the aircraft a hinged nose for a front-loading cargo door.

The first design for the cockpit enclosure was a hemispherical hump atop the fuselage. This produced too much drag, so Boeing extended the aft portion of the hump to form a teardrop. Then, in a deliberate echo of the below-deck lounge on the model 377 Stratocruiser, Boeing's 1940s flagship, Trippe and his colleagues persuaded Boeing to turn the extra space behind the cockpit into a bar and lounge.

The party days ended with the 1973 fuel crisis, when virtually every 747 operator got rid of the lounge and replaced it with more seats for paying passengers. In announcing the change, a British Airways press release noted that the upstairs area was "currently used for a first-class lunge"—the spelling was probably appropriate more often than not.

The décor in the 747 lounge is a vaguely horrible memory, but burnt-orange sectional sofas weren't the only aesthetic transgression to come out of Seattle during that era. There was the 747SP. This short-body, long-range version of the 747 was as economical as it was elegant (that is to say, not at all), but when Boeing sawed 47 feet out of the fuselage to create the SP, the engineers had to look at what would happen when the rear of the cockpit hump lined up with the front of the wing. There were no ill effects, as it turned out, so Boeing designed the new 747-300 with a longer upper deck to seat up to 70 passengers.

Today's 747 has a large upstairs cabin because Trippe thought it would be a freighter, because a round hump produced too much drag, because Pan Am bosses had fond memories of the Stratocruiser's bar (and all-night parties held by the light of the Pratt & Whitney R-4360s' flaming exhausts), and because fuel prices went through the roof. Nobody set out to design the air-

The history of the airplane is remindful of biological evolution. New species emerge through mutation and then survive or perish.

plane with an upper deck. It came about because it was possible and because it adapted the 747 to a changing environment. It evolved.

The history of the airplane is remindful of biological evolution. New species emerge through mutation and then survive or perish. In detail, every part of an airplane is designed deliberately and meticulously for its job. Nine times out of ten, though, the broad layout of the airplane is evolutionary.

Trace the line back and you will find an airplane that looks new and revolutionary—only to find that its own design is usually the happy combination of many strands of previously existing DNA, with results that the designers themselves never quite foresaw until the airplane was complete.

Most large commercial jet aircraft—even those designed by arch-rivals—look like members of the same family. Their engines hang on pylons, in front of and below their swept-back wings. The landing gear is in exactly the same place: hinged behind the rear wing spar and folding inward to stow behind the wing. The wings all have lift-boosting devices—flaps—across their leading and trailing edges.

All these airplanes carry the DNA of a common ancestor: the Boeing 367-80, also known as "Dash 80." That Boeing 707 prototype, in turn, emerged from a tumultuous nine-year process as the third in a sequence of significantly different airplanes, the first two being the B-47 and B-52 jet bombers.

In 1945, after Allied armies had secured German research files, Boeing aerodynamicist George Schairer unearthed a goldmine of data the Germans had compiled on swept wings. Boeing promptly junked its Model 432 straight-wing jet bomber design in favor of what would eventually become the B-47, which shared its new features—"bicycle" landing gear, swept wings, and pod-housed engines—with a Junkers design, the EF 150, that had never been built. (Unknown to Boeing, the EF 150 designers had been taken to Russia to complete their work; see "The Rise and Fall of the East German Aircraft Industry," Feb./Mar. 1996.)

The Strategic Air Command learned to live with the B-47's deficiencies and vile habits because the Stratojet was faster than most Soviet fighters. Too fast to land safely, B-47s trailed two braking parachutes. Underpowered, the bombers were fitted with booster rockets for takeoff. Short on range, Stratojets were refueled in flight by a fleet of hundreds of SAC tankers.

Boeing corrected many of the B-47's problems by improving the wing and engines in its next heavy bomber design, which could have fit the intelligent design theory had it led to a commercial jet or transport. But its conceptual design phase encompassed a weekend marked by an atmosphere of crisis in a hotel room in Dayton, Ohio: the B-47 follow-on was in trouble.

In October 1948, three senior Boeing engineers had a bad-news Friday meeting at Wright-Patterson Air Force Base in Dayton. Weary of problems with the engine installation on Boeing's new heavy bomber, the Air Force made it clear that the project was all but dead.

But two other Boeing engineers were also in Dayton and working on a study for an improved B-47-size medium bomber with a better wing design and better engines. Over the weekend, the Boeing team projected that airplane's characteristics into a larger, eight-en-

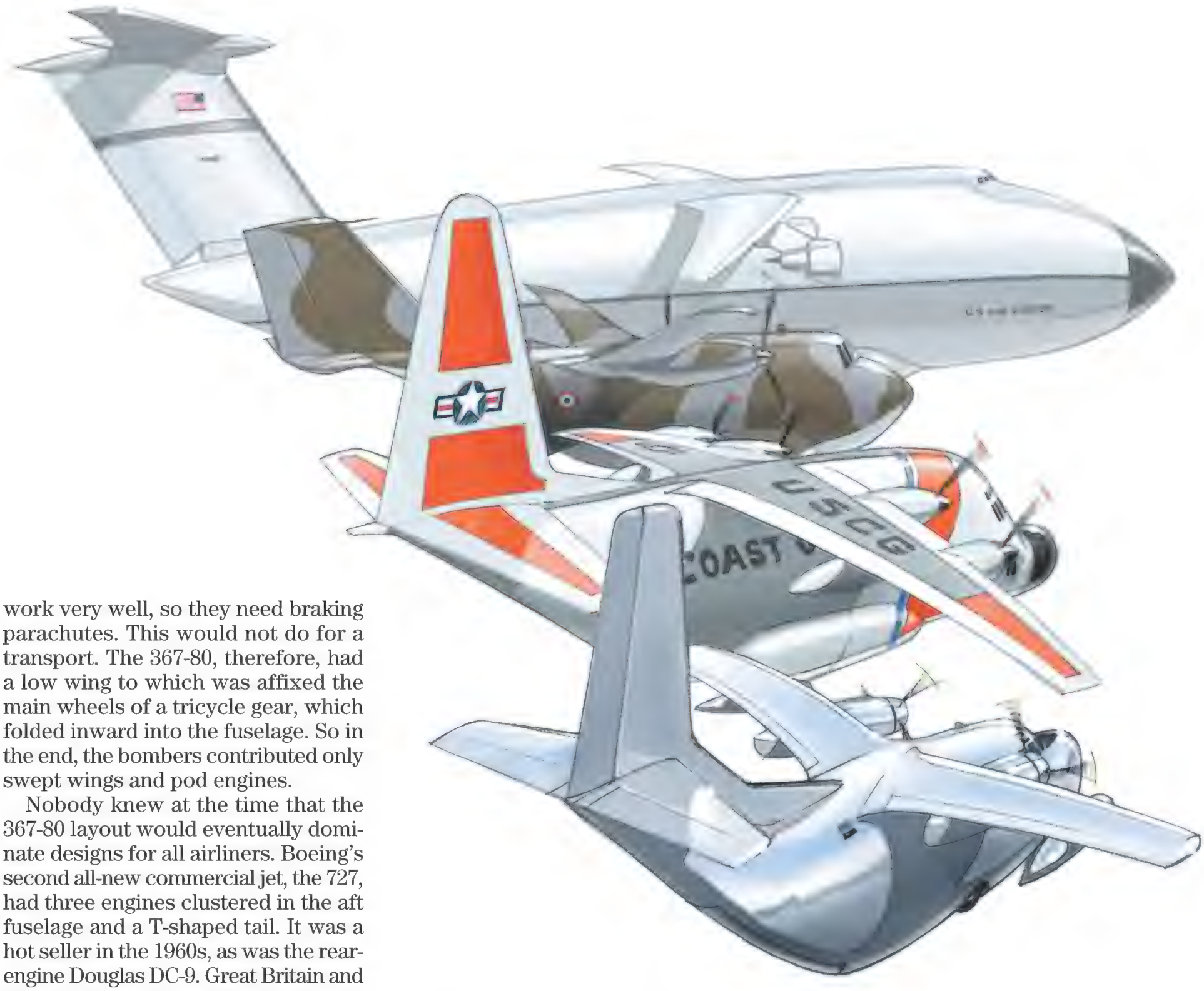
Aft-mounted engines in pods once typified small to mid-size airliners, but now only business jets are configured this way.

Hung from the wings of bombers, the turbojet found a home. Now all big jets look as much alike as peas in a...well, you know.

gine design. George Schairer bought balsa wood and tools at a hobby shop, and by Monday, the Boeing team had a model to accompany its presentation. The project won a reprieve, and Schairer posed for a publicity photograph with the model in his hands. It is quite recognizably a B-52.

Boeing's first idea for a jet transport incorporated the swept wings and podded engines of its bomber predecessors, but it also shared a high wing. With the wing on top of the fuselage, the only place for the landing gear was in the belly, arranged like a skateboard's wheels—ahead of and behind the airplane's center of gravity. The tricycle gear on an airliner places the main gear close to the center of gravity, with just enough weight forward to ensure that the airplane stands lightly poised on its nosewheel. On takeoff, every airliner pivots (or "rotates") on its main gear, noses up, and climbs away at an angle.

But because of the tandem bicycle landing gear arrangement on Boeing's bombers, they can't rotate to climb any more than your car could. To take off, the bombers' wing has to be in a flying attitude to generate lift on the ground, and that's how they're built: with the wing at a positive angle of attack. They both land and take off with their fuselage—and landing gear—in a level attitude, levitating more than climbing, settling more than descending. On rollout after landing, the wings generate lift and the wheel brakes don't



work very well, so they need braking parachutes. This would not do for a transport. The 367-80, therefore, had a low wing to which was affixed the main wheels of a tricycle gear, which folded inward into the fuselage. So in the end, the bombers contributed only swept wings and pod engines.

Nobody knew at the time that the 367-80 layout would eventually dominate designs for all airliners. Boeing's second all-new commercial jet, the 727, had three engines clustered in the aft fuselage and a T-shaped tail. It was a hot seller in the 1960s, as was the rear-engine Douglas DC-9. Great Britain and France produced rear-engine jets, including Britain's 707-size Vickers VC-10 and France's early Sud Caravelle. The 707 looked positively dated.

And yet today, the last of the paltry 54 VC-10s, converted into military tankers, roar and snort their way around the world. The last 727 rolled off the production line in 1984, replaced by the underwing-engine 757. Europe adopted the Boeing-style shape for the Airbus A300—and for the first time had an airplane that the world wanted to buy. Today, the Boeing 717—the rebadged tail end of the DC-9 line—is the last rear-engine, 100-plus-seat jet in production.

Underwing-engine airplanes evolved and became dominant because they were more efficient. An airplane's wing is like a beam with the mass of the fuselage at its center; engines hanging at mid-span on the wing counteract some of the bending loads on the beam, so the wing can be built lighter. With the weight of the engines at the back, an airplane balances nicely with a shorter aft fuselage, so the horizontal stabilizer has less leverage to balance the airplane and must be bigger and heavier. British reports bragged that the VC-10's all-moving tail was bigger than the wing of a Hunter fighter—but it weighed a ton.

Iguanas and Komodo dragons survive after allosaurs die out. Almost all business jets and most regional jets still have aft engines and high tails. In 1959, McDonnell actually did try to adapt the 707 shape to a small airplane; the result was the model 220 prototype, a competitor for an Air Force contract for a utility transport and trainer. It looks like it might be a 707's awkward chick, a creature that has some growing to do before it can fly.

The ramps have it: For 50 years, every military cargolifter has sported a high wing and tail, with landing gear tucked into cheeks along the belly—all to provide an unobstructed hold for cargo, with a drive-on ramp to speed loading.

The model 220 shows that 707-style underwing engines don't adapt well to small sizes. You can scale down an airplane but not the air; the gap between the engine nacelle and the wing cannot shrink in proportion to the airplane. While the forward cabin door is high off the ground, the engines' ground clearance is reduced and the inboard engine is in line with the bottom of the steps, perfectly positioned to eat the impatient CEO who won't wait for the engines to shut down.

The C-130 did not spring from a clean sheet of paper. It owes a lot to some little-remembered airplanes that link it to the transport gliders of World War II.

Military transport airplanes all look like Grandpa: the Lockheed C-130. It has a high-mounted wing, a stumpy-legged main landing gear in pods on the lower corner of the fuselage, and an upswept tail that incorporates a ramp door. The ramp can be lowered to the ground so that vehicles can drive in, it can be extended straight out to roll cargo pallets onto or off a truck, or it can be opened in flight to drop loads out the back by parachute.

For a brief period between World War II and the Korean War, it appeared that a very different configuration would reign, with a central pod fuselage and twin booms supporting the engines and tail—see the Fairchild C-82 Packet and C-119 Flying Boxcar in the United States and the Nord Noratlas and Armstrong Whitworth Argosy "Whistling Wheelbarrow" in Europe. But that species was doomed.

The C-130 did not spring from a clean sheet of paper. It owes a lot to some little-remembered airplanes that link it to the transport gliders of World War II and, via a forgotten experiment, to the Douglas DC-3 and its military derivative, the C-47. In 1943 and 1944, the U.S. Army Air Forces wanted to replace its C-47s with four-engine Douglas C-54 transports. This entailed replacing its transport gliders, as the steel-tube-and-fabric airplanes could not survive in tow at the C-54's 250-mph cruising speed. As an experiment, USAAF engineers at Wright Field in Ohio stripped the engines from a war-weary C-47. Not only could the modified airplane be towed faster, but it had a low stall speed and a good glide ratio, both of which promised to make glider landings much less dangerous.

So the Army ordered two new high-speed gliders from the Chase Aircraft Company. The XCG-18 and the bigger XCG-20 shared three features: a high wing, a short, body-mounted landing gear, and a high tail. There was no ramp, but the tail was designed to stay clear of the ground when the glider landed. The XCG-18 flew in December 1947, but the USAAF had become the U.S. Air Force, and the U.S. Air Force liked supersonic fighters and jet bombers, not poky trash-hauling gliders. Chase fitted it with two engines, producing the C-122, a handful of which were built for the Air Force. Like a dinosaur with feathers, the C-122 was a link between gliders and airplanes: It still had a towing hook and could hitch a ride from another airplane to extend its range. The bigger XCG-20 acquired engines—as the C-123—before it was built.

One of Germany's largest wartime transports was the Junkers Ju 290, adapted from the Ju 90 airliner. The Ju 90 had a tail-wheel landing gear, with a nose-high ground attitude and sloping floor that made it hard to load cargo. Junkers engineers installed a powered ramp under the tail, which raised the airplane into a horizontal attitude as it opened. After the war, the USAAF tested a captured Ju 290 (nicknamed "Alles Kaput"), and the ramp subsequently appeared on the C-123.

Fairchild, which acquired Chase, built more than 300 C-123s. The C-123 still looks enough like a C-130 to double for the Lockheed airplane when a movie script calls for a military transport and the Air Force won't cooperate. C-123 credits include *Con Air*, *Outbreak*, and most Vietnam war movies in which the bad guys are Americans.

The fossil record of the creatures leading to the C-130 is hard to find because it includes a few obscure aircraft. Tracing the lineage can be more difficult if the missing link was never built.

In March 2001, Boeing unveiled the concept for an airplane called the Sonic Cruiser. A canard (tail-first) design with a compound-sweep wing and engines carried on a "back porch" extension of the wing, it looked different from any airplane Boeing had ever built. The missing link, hiding in a NASA presentation in an obscure corner of the Internet, was a Boeing supersonic transport design that—except for a pointy nose and different engines—was clearly the Sonic Cruiser. It didn't look like anything else out of Boeing, but the aft-set, compound-swept wings and the engine location made the aircraft look very much like a series of supersonic designs from the 1990s by Sukhoi, a Russian aircraft company with which Boeing has partnered to develop a regional jet airliner. Late in 2002, Boeing cancelled the Sonic Cruiser—but don't be surprised if this resilient gene strand pops up somewhere else before too long.

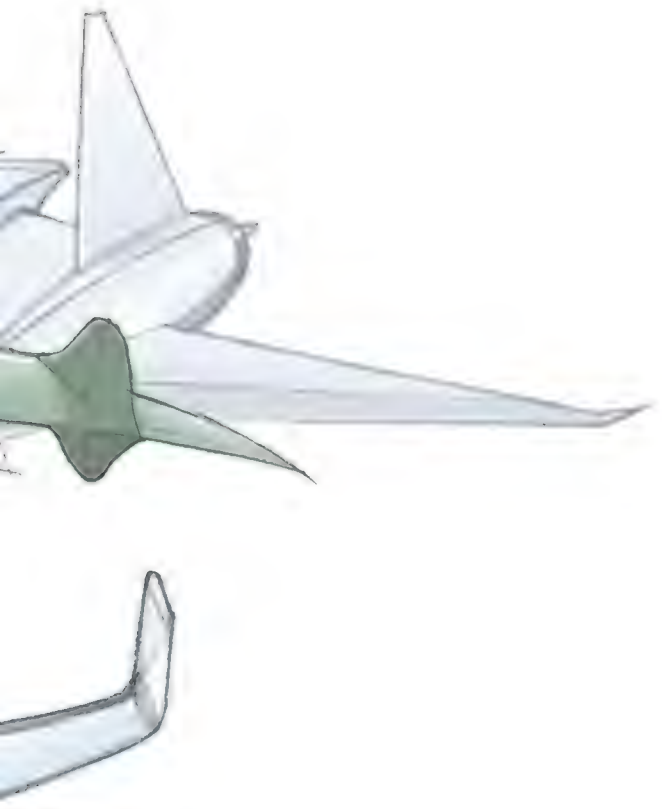
The coelacanth is a creature that was so well adapted to its marine reef environment that it did not need to evolve despite more than 300 million years of existence. In St. Augustine, Florida, Northrop Grumman still builds the E-2C Hawkeye for the U.S. Navy and export customers. The long-wing, twin-engine airplane, with a radar dish sitting on its back like a friendly UFO, no fewer than four vertical tails, and its Grumman folding wing, which looks

About every 20 years or so, designers seem to commemorate the Wright Flyer *with yet another canard—tail-first—design. Within another 20 years, they're forgotten.*

double-jointed but isn't, is entirely suited to the task of carrying a radar off a carrier. The production line started moving in 1960 and shows no signs of stopping soon.

Lockheed Martin's U-2 is a serial coelacanth. The Central Intelligence Agency, which sponsored the original design in 1954, planned to build 30 airplanes and fly them until Soviet surface-to-air missiles improved to the point where the aircraft could be shot down. The CIA thought this would happen about 1960, and it did, but the agency continued fielding the U-2 because of its ability to carry heavy loads to

The aft-set, compound-swept wings and the engine location make the Sonic Cruiser look much like a series of supersonic designs from the 1990s by Sukhoi, a Russian aircraft company.



high altitudes. The production line was restarted once in 1967 and again in the early 1980s, and every few years Lockheed Martin floats a proposal to start it yet again.

Some designers and organizations have a stronger record of creating enduring mutations than others. Europe's Airbus has prospered by steadily evolving and refining the Boeing-type commercial airliner—and a very good job they have done of it. But the Fort Worth division of General Dynamics—now part of Lockheed Martin—went through a four-decade cycle in which none of its major airplane projects bore any resemblance to its predecessor—or, for that matter, to anything else.

The lumbering, 10-engine B-36 bomber, bristling with retracting gun turrets like a Star Wars cruiser, was followed by the compact, fast, and dangerous B-58 Hustler and the swing-wing F-111—all unique designs. When GD chief designer Harry Hillaker and his team went after an Air Force lightweight-fighter contract in 1970, the world was skeptical. Fort Worth had never produced anything that weighed less than a fully loaded semi-trailer.

Doubts increased when Fort Worth rolled out a fighter shrink-wrapped around one massive engine, with blended wings and an under-body air inlet, an airplane that would not fly straight without computers. Bill Gunston, doyen of British aerospace journalists, observed that some air forces harbored a "cavalry officer mentality…that just wanted a flashy horse that would go faster." The GD fighter, Gunston wrote, "was like selling the cavalry officer a super horse with six legs." Four thousand F-16s later, one has to conclude that Hillaker and his team knew more about fighters than they had been given credit for.

Lockheed's Skunk Works is another organization with a reputation for breaking with tradition. In addition to the U-2 and the Mach 3 SR-71 Blackbird, the Skunk Works was responsible for the first stealth attack fighter: The F-117, without a single curve in its exterior surface, had to be unique, because it was the first airplane designed with reference to two equally important physical environments: the air and the electromagnetic spectrum.

Robert Silverstein, who was a Northrop Grumman executive in the early stages of the B-2 project, has compared the strange world of black projects to Australia: an isolated area where unique species can evolve without being gobbled up by bigger, more established predators. Now, the F-117's DNA is showing up all over the place. Look at the F-22 Raptor stealth fighter, particularly in front view, and then flip it upside down: There is the F-117's profile, softened only by a few rounded edges and gentle curves. And the new F-35 Joint Strike Fighter is the F-22's cousin.

Maybe it's the climate. Maybe it's radiation leaks. Either way, a lot of strange mutations have sprung up in the Mojave Desert. The place shelters not only the black world's equivalent of Edwards Air Force Base—the secret Groom Lake, Nevada facility—but also the town of Mojave, home of Burt Rutan's Scaled Composites company. If most airplanes evolve by natural means, then Rutan is aviation's Dr. Frankenstein, fashioning strange asymmetric creatures (Boomerang) and others with so many arms and legs you lose count (Proteus, ATTT).

Sometimes you know it's all going to end in tears. Take the example of Raytheon, which thought of itself in the early 1980s as a Route 128 Massachusetts technology company. Hoping to revitalize its fuddy-duddy Beech unit in Wichita, Kansas, Raytheon bought Scaled Composites. "It was like asking Ed 'Big Daddy' Roth"—the king of the California hot-rod customizers—"to design the next Cadillac," Mike Potts, a former Beech executive, observed later. Rutan enlarged his two-place canard VariEze homebuilt into the turboprop-powered Starship. Beech built it and unveiled a full-scale mock-up at the National Business Aircraft Association convention in Dallas in 1983. Every Beech dealer was prevailed upon to accept one airplane.

Some said the market wasn't ready for such a radical departure. Others said the market wasn't ready for anything. Whatever the case, the Starship production line closed after 53 airplanes had been built.

The risks and rewards of radical change can be huge, but sometimes you end up with something better kept chained in the dungeon—and that is why evolution rules, in aviation as well as in nature.

THE PENT
SAUC

Under a clear blue sky on May 27, 1959, the doors of a hangar at Toronto's Malton Airport parted with a rumble. As a crowd of reporters watched, fascinated, four men in white lab coats rolled out what looked like an enormous aluminum cough drop.

Bearing both U.S. Air Force and U.S. Army markings, the waist-high disc was introduced to the press by Avro Canada, its builder, in a promotional film that showed it skimming a few feet above fields, grass and dirt swirling around it. "This unconventional circular vehicle, known as the Avrocar, rises vertically and travels over the ground on a cushion of air," intoned the film's narrator. "It will be able to operate without prepared bases and travel over terrain beyond the present capability of wheeled or tracked vehicles."

Here, then, was a machine that promised to be as useful in the cold war as today's unmanned aerial vehicles are in Afghanistan—and one based on the same idea: a platform that could either hover or fly, depending on the mission. The saucer was touted as capable of watching the enemy or darting off to intercept his aircraft and shoot it down.

But what the vehicle actually did could in no way be called "flying," says Fred Drinkwater. He should know; he tried to fly it. "This one violated every aerodynamic stability and control concept imaginable," the retired test pilot recalls.

Disappointing performance eventually doomed the military's interest in the disc, but some of the technologies developed for the craft survive today in more successful vehicles. One such offspring, a small aerial robot called the Moller Aerobot, has been given the job of in-

by Graham Chandler

And why test pilots wanted no part of it.

specting bridges for the California Department of Transportation.

And the public continues to be fascinated with both the concept and its history. Recently, Canadian librarian Bill Zuk delved into the details of the somewhat mysterious program, eventually authoring the exhaustive history *Avrocar: Canada's Flying Saucer*. MidCanada Productions and Discovery Canada are preparing a documentary on the project—"Avrocar: Saucer Secrets from the Past"—for broadcast sometime this spring.

Conceived in 1952 by a talented British engineer named John Carver Meadows Frost, the concept was initially funded by Avro Canada. However, when development costs were projected to exceed $200 million (in 1952 dollars), the company backed off.

Then a customer with deep pockets stepped up: the U.S. Air Force. It was the middle of the cold war, and the Air Force liked Avro Canada's vision of the saucer one day soaring to 100,000 feet, dashing off at 1,500 mph to bring down a Russian bomber, and returning to a vertical landing. In 1954 the service agreed to bankroll feasibility studies for variations on Frost's design.

In response, Frost's team, named the Special Projects Group, dreamed up a series of ever-wilder supersonic vertical-takeoff-and-landing flying saucers. But experiments with test models repeatedly failed. Avro needed to come up with something convincing, a proof-of-concept vehicle that would inspire the Air Force to increase funding.

Meanwhile, the U.S. Army had emerged from the Korean War craving an all-purpose flying jeep, a platform that could hover and fly close to the ground for reconnaissance, light battlefield resupply, pursuit, or harassment. In 1957, Avro, learning of this interest, drew up a proposal and presented it to both the Army and the Air Force: The company would develop a saucer-shaped flying machine that could maneuver as precisely as a helicopter but, with its more streamlined shape, achieve much greater speeds.

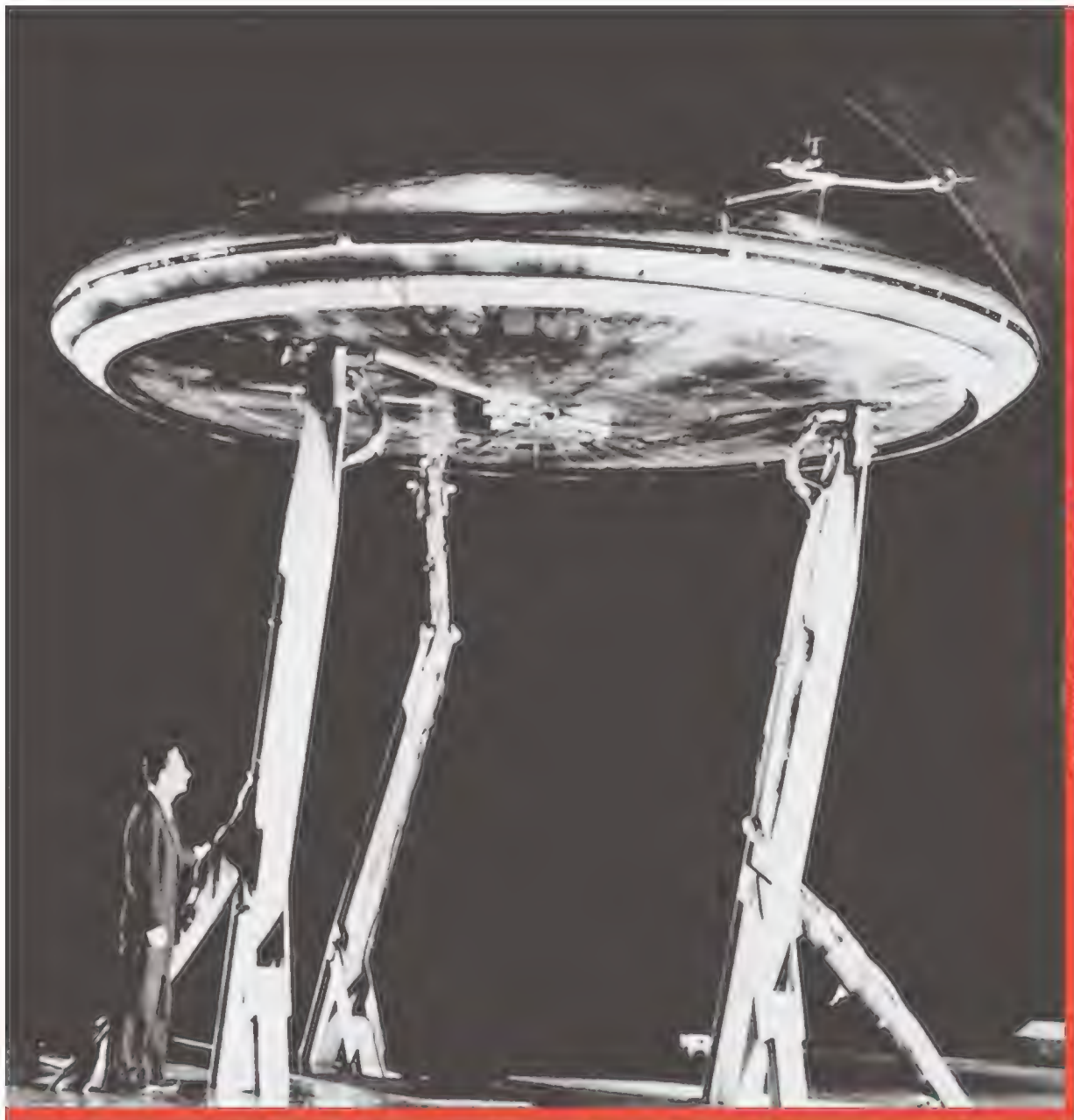
The following year, Avro inked a contract with both the Army and the Air Force in which it agreed to build two identical prototypes. The specifications: maximum weight, 5,650 pounds; powerplant, three Continental J69 engines producing 927 pounds of thrust each; maximum speed, 300 mph; range, 80 miles; and most importantly, the ability to hover out of ground effect—the phenomenon in which lift is assisted by the cushion of air under the craft. Officially designated VZ-9-AV, the design was dubbed the Avrocar.

While the Special Projects Group got busy converting the specs into blueprints, one of the members had the foresight to buy up lakefront property in Ontario's cottage country, two hours to the north. Now retired, Don Whittley spends the warmer six months of the year there. Today, he and I are having coffee and enjoying the view of the shimmering lake as he looks back on his days as an aerodynamicist assigned to work on the Avrocar.

At first, Whittley recalls, the team could not work up much enthusiasm for the vehicle. Frost had initially envisioned a hypersonic craft that could touch the edge of space, but the Army/Air Force incarnation was decidely less dazzling: "The Avrocar was really a fallback program," he says. But, the team figured, "at least now we finally had an opportunity for some full-scale testing."

The group brainstormed into the evenings. First it decided that giving the vehicle a disc shape, rather than the spade shape Frost had first proposed, would improve its ability to both hover and maneuver. With a circular shape, "you could send air out in any

U.S. ARMY TRANSPORTATION MUSEUM, FORT EUSTIS, VIRGINIA



DAILY ST

WEDNESDAY, APRIL 6, 1960—60 PAGES

SAUCERS
COULD RE

Tests at a NASA wind tunnel (above) showed that the Avrocar would not be stable at high speeds. At its rollout the year before (right), Avro had bragged about the saucer's military potential (below).

direction," says Whittley. But exactly how would you harness the jets' blasts to do this? The team settled on the idea of a controllable flap around the entire circumference of the saucer—the members called it a focusing ring.

The next question was how to direct the three engines' thrust evenly around the ring. The team devised an internal ducting network that carried the exhaust through a 90-degree turn and then took it out to the circumference of the saucer (see diagram, opposite).

Calculations showed that the jet exhaust could also be harnessed to drive a separate rotor in order to generate more thrust. The jets were therefore arranged so their exhaust was direct-

U.S. ARMY TRANSPORTATION MUSEUM, FORT EUSTIS, VIRGINIA (4)

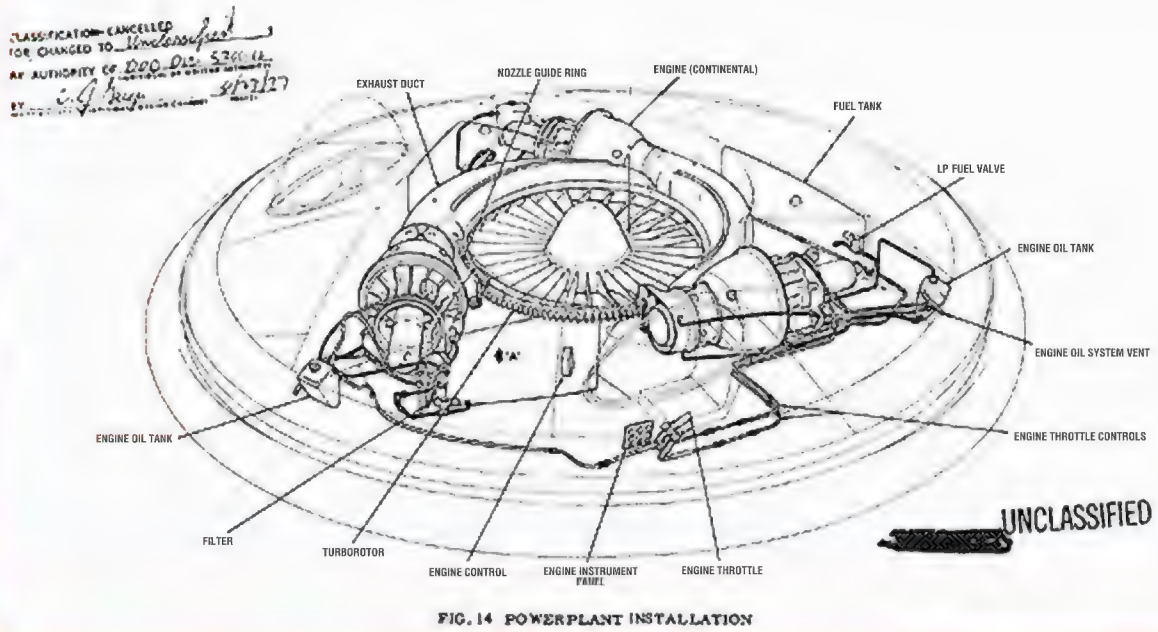


FIG. 14 POWERPLANT INSTALLATION

Thrust for the Avrocar was produced by three engines, as well as by a central "turberotor" that the engines' exhaust drove. For hovering, a focusing ring (not shown) at the saucer's circumference directed the exhaust downward.

ed at the tips of a five-foot-diameter rotor mounted horizontally in the saucer's center. Thus driven at high rpm, the rotor sucked air from above. The ducting network carried that air, along with the jet exhaust, outward. For hovering, the pilot would use the stick to actuate the focusing ring, which directed the exhaust evenly downward. For transitioning from hover to forward flight, the team designed two control surfaces: "transition doors" redirected the flow in the aft third of the saucer from downward to rearward, and control vanes would then deflect it up or down for pitch or roll control.

But the engineers predicted that as the Avrocar transitioned off its cushy ground bubble and picked up speed, it would be unstable in pitch. The pilot would be continually jockeying the stick back and forth to prevent it from stalling nose-up or pitching nose-down into the ground. In most conventional airplanes, the horizontal stabilizer looks after that. The Avrocar had no tail, so the team designed an ingenious mechanical connection that automatically deflected the control vanes up or down, simulating the effect of a tail. Slight horizontal motions in the spinning rotor would automatically control those vanes, so the pilot could occupy himself watching for the enemy.

So far, so good. After the rollout fanfare, Avrocar No. 1 was mounted in a test rig to put theory to practice. Engines were fired up. But as the throttles were advanced to full power, elation fizzled. The J69s' combined thrust, 2,700-plus pounds of it, wasn't producing the effect predicted.

The engineers deduced the problem: The air sucked in from the rotor was cold and the jet pipe exhaust was hot, and when the two were mixed, the resulting flow was turbulent and would not stick to the duct's inside walls. The result: 30 percent of the thrust was lost.

The team tried various tricks, but nothing budged the Avrocar out of ground effect. Though the Army had firmly required that achievement, the company "decided to carry on and fly the Avrocar at a reduced thrust level in the ground cushion, and modify the duct at a later date to pick up the missing thrust," Frost later wrote.

The team members pressed on toward a first flight. At least they'd have some kind of milestone to crow about. Avrocar No. 2 was chosen for the attempt. To prevent another surprise, the team used three stout cables to tether the saucer to within a few feet of the ground.

In September 1959, company test pilot "Spud" Potocki climbed in and lifted off for the first time. He spent the next six weeks feeling the Avrocar out on its leashes. By early December he was ready to throw off the tethers.

From a hover, he eased the stick forward. Canopy off (in case a quick exit was called for) and engines screaming, the Avrocar skittered over the tarmac, blasting dust and debris, rocking and dipping like a Frisbee in slow motion. It was an amusing spectacle, but not terribly impressive. Potocki could not get the saucer to exceed 30 mph, or to rise up more than three feet into the air and off its ground cushion.

The team faced a Catch-22. Avro could ask for more funds to cover a pricy redesign of the ducts, which might help the saucer lift out of the ground effect. But the effort would be wasted if the company couldn't demonstrate stability. And how could the engineers determine stability if they couldn't get the vehicle out of ground effect?

The solution turned out to reside with NASA. The Air Force had the Avrocar brought to the agency's Ames cen-

Its two cockpits gave the saucer a cartoonish face (above). When the program ended, one Avrocar went to repose at the National Air and Space Museum's restoration and storage facility (below).

ter in northern California for testing in the facility's 40- by 80-foot wind tunnel. To see how stable the craft would be in free flight, NASA set it up on 12-foot legs, like a creature from *The War of the Worlds*, and equipped it with movement-sensing instruments.

The testers cranked up the wind to simulate airspeeds over 30 mph, and stability did in fact deteriorate. To see if a pilot could keep the craft level at such speeds, the engineers sent NASA test pilot Fred Drinkwater to Toronto to try flying the other Avrocar.

Today, relaxing on his deck in California and eyeing the hummingbirds among the hibiscus, Drinkwater recalls inheriting the flying saucer from his predecessor: "I met Spud, he briefed

RIGHT: ERIC LONG, NASM; TOP: U.S. ARMY TRANSPORTATION MUSEUM, FORT EUSTIS, VIRGINIA

me, and within an hour I was flying—hate to use that word—first tethered, then a free flight."

Drinkwater says the saucer wasn't difficult to operate. "To lift off you just added full power. It hovered easily." Then he tried to gather enough speed to escape the ground bubble. "Desmond Earl [Avro Canada's chief aerodynamicist] insisted you could get out of ground effect by charging forward and suddenly pulling up," he recalls. "But after repeated tries, I never could get it to do that. It just kept going like a wobbly saucer."

I ask if the wobbling could have been caused by PIOs—pilot-induced oscillations—a phenomenon in which the pilot's attempts to correct pitching motions actually increase their amplitude, rather than diminish them. Drinkwater laughs. "You couldn't *get* it to PIO," he says. "It wasn't that responsive."

Avro tried yet another angle: getting a pilot with no helicopter or VTOL familiarity—one who could approach the flying without bringing potentially counterproductive habits to bear. Avro test pilot Peter Cope strapped in and tried. Flying it four times, he had no more luck than the previous two pilots. "It was a very dirty thing to fly," he recalls today from his Bellevue, Washington home. "The canopy would ice over, so I had to fly it with an open cockpit." As the saucer flew past at 30 mph, it churned up ice and water from puddles on the tarmac, drenching Cope in spray. "You could hardly see anything," he says.

His attempts did, however, succeed in entertaining the passengers of Viscount turboprops passing by on Malton Airport's nearby taxiways. "I could see all their faces pressed to the windows," he says.

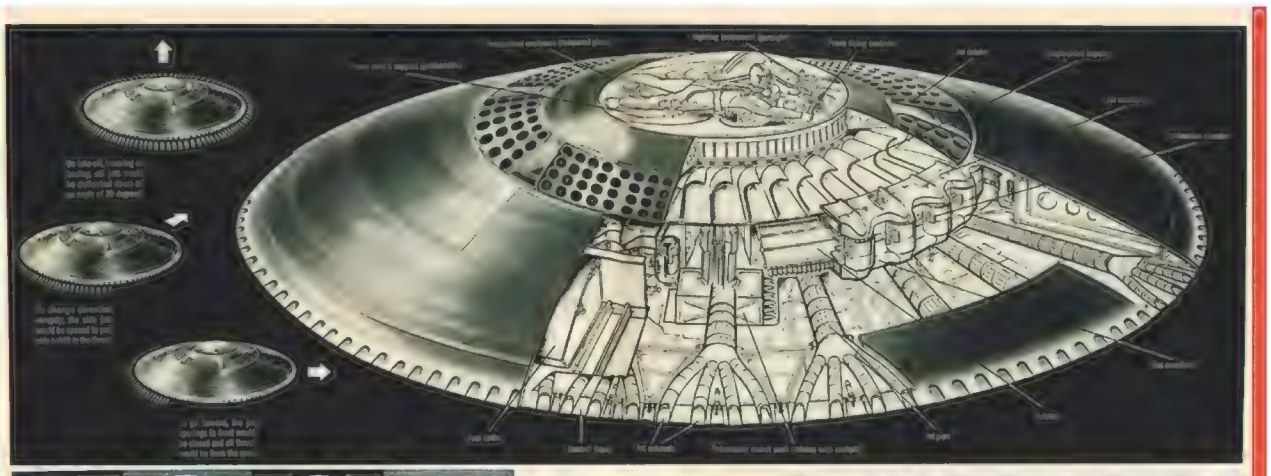
Over the course of 10 years, Frost's dream had shrunk from a saucer tearing off at 1,500 mph and 100,000 feet to one chugging along at 30 mph and three feet. In December 1961, having spent a total of $10 million on the program, the Pentagon canceled it.

But as the Avrocars sat around attracting little more than dust, their legacy lived on. In 1961, when the saucer was turning heads at Malton Airport, a 24-year-old named Paul Moller was working at Canada's Defence Research Board; because he had a security clearance, "I was therefore able to study the Avrocar in detail," he recalls. "I immediately committed to a design of my own." At the University of California at Davis in 1966, he built and flew a one-seat VTOL saucer. Since then, he has produced ever-more-complex VTOL vehicles. Today, his company, Moller International, offers the Aerobot and the M400 Skycar, "the first and only feasible, personally affordable, personal VTOL vehicle," in his words.

Moller says that he has learned important lessons from the Avrocar. He believes the design was doomed at least in part by the 90-degree turn the exhaust had to make—a turn that caused the exhaust to detach from the duct's walls and therefore lose thrust. In his Skycar, no such turns are necessary. The propellers are in pods, which can be tilted almost vertically to achieve hover.

Avrocar No. 2 is now being restored for an indoor display at the U.S. Army Transportation Museum at Fort Eustis, Virginia. The other one is at the National Air and Space Museum's Garber facility in Suitland, Maryland, awaiting a rebuild and a nicer home at the Museum's new complex in northern Virginia, currently under construction.

So despite test pilot Fred Drinkwater's tales of disappointing performance, the Avrocars still made it into aviation's halls of fame. And even if, in his estimation, the saucers didn't really "fly," he has to admit: "The whole idea sounded really great."



LOOK

A blueprint for flying saucers

is this the real **FLYING SAUCER ?**

DESPITE HUNDREDS OF "eyewitness" accounts of flying saucers, none has been captured and no government has come forward to take credit (or blame) for their reported aerial shenanigans. So, barring the possibility that the saucers are from other planets, it seems reasonable to conclude that "there ain't no such animal."

But persistent and fairly credible rumors persist that a Canadian aircraft manufacturer, A.V. ROE. CANADA LTD. has had a saucer design under development for two years. The A. V. ROE people maintain a confusing silence about the whole thing. They can't deny that the project has been abandoned because they never announced that it had begun.

To report on the classified program, the press had to make do with artists' conceptions and rhetorical questions. Former employees think Avro leaked optimistic projections to the press in order to raise funding.

AVRO'S CUP OF TEA—OR "CRACKED" SAUCER?

Avro Saucer Joke or What?

METRO EDITION

Reports that Avro would have a flying saucer in the air over Toronto within two months brought a deluge of conflicting opinions from high officials in Washington and Ottawa today.

A spokesman in the department of national defence said he had learned Avro might test a hand-made model of the saucer "within a few months" to determine whether certain revolutionary principles of flight will be successful.

But a former Liberal cabinet minister scoffed at reports Avro officials were pinning their hopes for the Canadian aircraft industry on the saucer.

In Washington, top defence officials indicated they had pretty well given up hope the company's experiment would come to anything.

The company holds a U.S. air force development contract estimated at anywhere from $6,000,000 to $8,000,000 for a vertical rising aircraft.

"So far, we can't see any great hope for the future," said one official, "but we may continue the contract in case the company can turn up something."

The former cabinet minister who was directly involved in the Liberal government's decision to withdraw support of the project in 1955 said the saucer "was of no use to Canada whatsoever, either commercially or militarily."

Speculation that the completed saucer could cross the Atlantic in two and a half hours was "ridiculous," he said.

"It's a vertical take-off plane and has no forward speed—or very little," he said.

He described it as similar in principle to a helicopter, using jet engines instead of propeller blades.

"I wasn't interested in the project in 1955 and I'm even less interested now," he went on. "It couldn't possibly pick up the slack left by the government's decision to kill the Arrow."

He described cancellation of the Arrow as "a dreadful way to do it."

Decision to cancel was made in September, he said, when the electronics contract for the aircraft was discontinued.

"The government should have used those six

(Continued on Page 2, Col. One)

U.S. ARMY TRANSPORTATION MUSEUM, FORT EUSTIS, VIRGINIA (2)

SIGHTINGS

Photographer Erik Hildebrandt's latest coffee table book, *Heritage Flight* (Cleared Hot Media, 2003), focuses on a series of formation flights by vintage warbirds and modern fighters, begun by the U.S. Air Force in 1997 as a novel way to commemorate its 50th anniversary. In the first Heritage Flight, a McDonnell Douglas F-15 and a pair of North American P-51s joined up for a show-stopping flyby. The Air Force went on to team its high-performance aircraft—Fairchild Republic A-10s, Lockheed Martin F-16s, and McDonnell Douglas F-15s—with civilian-owned and -flown World War II and Korean War aircraft—North American P-51s and F-86s, Lockheed P-38s, Republic P-47s—and took the show on the road. Today, Heritage Flight performs at over 100 airshows a year.

Right: Three generations of air superiority fighters (left to right): a North American F-86, North American P-51, Lockheed P-38, and McDonnell Douglas F-15 in "finger four" formation, so called because the positions of the aircraft resemble the fingers of the hand, with the longest finger at the lead. Below: Two types of Republic Thunderbolts get in your face: the P-47 "Jug" (top) and the A-10 "Warthog." "The shot is actually as close as it looks," says Hildebrandt, who shot it from the tail gunner position of the North American B-25 Mitchell *Lady Luck*. "I can clearly remember the growl of the Thunderbolt's prop chewing on the wake of the B-25." Below right: The Air Force Thunderbirds, whose history reaches back to 1953, when the team flew Republic F-84s, has its own show-stopper maneuvers, among them the knife-edge pass by the two solos. This never fails to draw gasps from the audience, to whom it seems that the F-16s miss each other by mere inches.

Art of the Airways

by Geza Szurovy. MBI Publishing Company, 2002. 180 pp., $39.95.

Once upon a time airlines had a terrific product to offer. Their big, beautiful posters—some fashioned by Norman Rockwell and Alexander Calder—hawked the romance of air travel for almost a century. Today they evoke bittersweet reactions, reminding us of how low air travel has sunk.

Geza Szurovy, a journalist and pilot, relishes the link between surviving aviation artifacts and the social history they represent. He's dipped into his own collection, as well as those of numerous archives, libraries, and airline companies, for this hefty assemblage of artwork, which dates to the earliest days of air transport.

Airline posters fall roughly into two categories: Some depict aircraft and others destinations. A 1950s poster by United Air Lines (rendered as three words then) shows happy visitors in a canoe cresting a giant wave off of Hawaii's Waikiki Beach. Airliners are nowhere to be seen, but the scene makes you want to climb aboard a DC-7 and fly to Honolulu. An Air France poster depicts a Boeing 707's shadow about to pass over a brightly lit Arc de Triomphe in Paris. The airline had cleverly extended the poster's life by altering the original silhouette of a Lockheed Constellation.

LUFTHANSA

On most posters aircraft are featured more prominently. A cutaway painting of a twin-engine Dewoitine D338 in a 1936 Air France advertisement is more charming than technical. Conversely, a three-view schematic of a Douglas DC-10 in a 1979 Finnair lithograph, accompanied by the airplane's vital statistics, seems aimed at the aviation enthusiast rather than the casual passenger; the technical stuff might even put off a traveler trying to forget that he is strapped inside a metal tube flying miles above Earth. Of more comfort is a 1930s painting of a golden-mopped Shirley Temple figure who points to a Northwest Electra and says encouragingly to a fledgling "See…it's just that easy!"

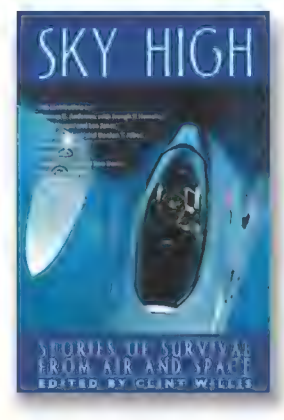
—Robert F. Dorr is the author of Air Force One.

COURTESY GEZA SZUROVY/ART OF THE AIRWAYS

Sky High: Stories of Survival From Air and Space

edited by Clint Willis. Thunder's Mouth Press, 2003. 305 pp., $17.95.

This collection is the 10th entry in the Adrenaline Books series, most of which deal with war, survival or both. Editor Willis' newest volume, *Sky High*, could better be described as a combination of survival, travel, and what were once called "adventure stories." Some live up to the book's title better than others.



On the plus side, the anthology includes as fine a narrative of a World War II dogfight over Germany as you're likely to encounter. This is an excerpt from P-51 ace

Clarence Anderson's book, *To Fly and Fight*, and it's a genuine page-turner. Close behind are Chuck Yeager's first-person descriptions of forcing the X-1 through the sound barrier and Yasuo Kuwahara's tale of life as a Kamikaze escort pilot. But by far the best of the autobiographical survival stories is Eugene Cernan's harrowing description of his Gemini 9 spacewalk, a stroll that nearly ended in disaster.

Two selections offer a glimpse of World War I combat. One is from *Fighting the Flying Circus*, written by U.S. ace Captain Eddie Rickenbacker, to whom the author's chapter introduction awards 22 kills instead of the correct 26. The other is from *High Adventure* by James Norman Hall, introduced in the chapter heading as a member of the Lafayette Flying Corps. Technically he was, but Hall is best known as a member of the Lafayette Escadrille.

Sky High provides diverting reading, but several of its 13 chapters do not deal with survival as a central event. Donovan Webster's lengthy piece on cropdusters, for example, demonstrates that he knows his subject, but he fails to communicate the stomach-churning world of those who fly below the powerlines to strafe insects.

Perhaps because of the recent Space Shuttle *Columbia* loss, I found Andrew Chaikin's well-constructed account of the fiery death of astronauts Gus Grissom, Roger Chaffee, and Ed White difficult to associate with "survival." David Roberts' memoir of bush pilot Don Sheldon is charming, but here again, the protagonist dies.

Sky High concludes with its oddest selection, a fictional account of the first moon landing as seen through the eyes of H.G. Wells. Interesting, but badly off strategy.

Most readers will learn something from *Sky High*, though much of the material is familiar. A good book to read while traveling, but no more than that. *—William Jeanes is a former editor in chief of* Car and Driver *and is a contributing editor to AutoWeek.*

BRIEFLY NOTED

Pacific Ghosts *(CD-ROM), narrated by Michael John Claringbould. Pacific Ghosts, $26.50.*

Justin Taylan came by his interest in the Pacific campaigns of World War II honestly; one of his grandfathers was a Filipino expatriate who assembled combat aircraft in a U.S. plant during the war, and the other was a veteran combat photographer. Now he has compiled a collection of information about aircraft wrecks throughout the Pacific, covering more than 30 aircraft of both U.S. and Japanese origin, many surprisingly well preserved. This CD offers both still and video images, along with cockpit views and location maps.

To Hanoi and Back: The U.S. Air Force and North Vietnam, 1966-1973

by Wayne Thompson. Smithsonian Institution Press, 2002. 416 pp., $31.95.

This new history is certain to become a major reference work for any serious scholar of the Vietnam War. Thompson, chief of analysis at the Air Force History Support Office, brings a great amount of knowledge and experience to the table.

This highly readable volume is an accurate and unvarnished account of Air Force involvement, and focuses on the Air Force's politics in the White House, in the cockpit, and everywhere in between. While the Navy complicated command and control by operating independently in designated regions, the Air Force split responsibilities in a more extreme way: by command. For example, the Strategic Air Command established its own set of rules for deployment of B-52 bombers and KC-135 tankers, while the Seventh Air Force controlled the in-country war and the 13th Air Force oversaw conflict outside Vietnam.

Thompson delivers a warts-and-all look at President Lyndon Johnson and defense secretary Robert McNamara's wasteful bombing campaigns in the north. The secretary of defense's theory of gradual escalation convinced the president that bombing could be turned on and off as a reward/punishment system and would force Ho Chi Minh and the leaders of North Vietnam to cave in to U.S. demands. In reality, halts in the bombing enabled North Vietnam to move and resupply units, improve defenses, and grow stronger. The administration's

Flying Route 66: A Sky Bum's Tour of the Mother Road (DVD)

by Russell Munson. Order from Sporty's, 1-800-LIFTOFF, product no. D400, $29.99.

Route 66, which was constructed in 1926 and ran from Chicago to Santa Monica, figures large in American legends, and though supplanted by the interstate highway system, it continues to cast a spell on travelers the world over. We are fortunate to count pilot and photographer Russell Munson among the spellbound.

Munson, a consulting editor at *Flying* magazine whose writing and photography have often appeared in *Air & Space*, has toured Route 66 at 500 feet many times and has compiled photos along with a history of what John Steinbeck called "the mother road."

The 40-minute DVD takes you along for the ride, from Chicago's Meigs Field to Santa Monica's Clover Field, some 2,400 miles. The most arresting photos are of Munson's Super Cub over Route 66 terrain, which could serve as advertisements; you'll want to run out and buy a Piper for yourself. Attractions like Cadillac Ranch and Meteor Crater are a gas; photos of the Mojave Desert and the tilled red earth in Oklahoma resemble NASA images of extraterrestrial landscapes. Munson's narration is equally mesmerizing. This mini-documentary is a fine blend of history, eye candy, and poetry. *—Patricia Trenner is the senior editor of* Air & Space/Smithsonian *and a sky bum wannabe.*

imposition of a multitude of restrictions, no-fly zones, and other rules of engagement also benefited the enemy and frustrated U.S. operations. Failure to adhere to the rules often led to disciplinary actions, such as the high-profile court-martial of General John D. Lavelle, recounted here in detail.

Upon assuming the presidency, Richard Nixon left restrictions in place, but when his patience ran out he unleashed massive air operations against Hanoi and Haiphong, including the B-52's Christmas raids. This campaign finally brought an end to U.S. involvement and the return of many of the American P.O.W.'s—mostly airmen shot down during years of operations in the north. Early proponents of the massive bombing raids seemed vindicated at last.

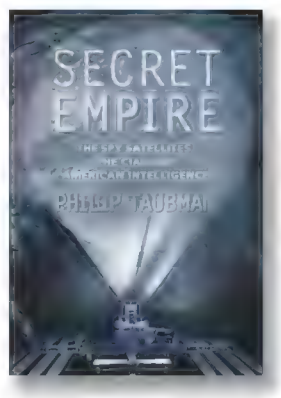
Thompson's impressive account of the period is supported by inclusion of more than a hundred pages of notes, statistics, maps, documentation, and bibliography. *—Lieutenant Colonel Bob Hanson, U.S. Air Force (ret.), flew 122 missions in F-4Es while assigned to the 469th Tactical Fighter Squadron at Korat air base, Thailand.*

Secret Empire: Eisenhower, the CIA and the Hidden Story of America's Space Espionage

by Philip Taubman. Simon & Schuster, 2003. 464 pp., $27.00.

Veteran military reporter Philip Taubman has written a gripping and important book about the evolution of America's high-altitude military reconnaissance during three decades of the cold war beginning in 1946. He deftly contends that elements of the U.S. government were so intent on perfecting the science and technology of spying that they neglected to properly fund enough ground-based human intelligence while spy planes and spy satellites eventually generated too much information to interpret and use in a timely manner.

In concentrating on the development of the CL-282 (otherwise known as the U-2) and the WS-117L—the United States' first orbiting spy satellite—Taubman uses a wealth of detail about flying conditions and political realities to convey the urgency that propelled the engineers, craftsmen, and airmen involved.



The author portrays President Dwight Eisenhower as a strong, intelligent, and farsighted statesman whose twin concerns about Soviet surprise attacks and the safety of American airmen (from 1950 to 1970 the United States lost more than 250 airmen in spy missions) set the nation on its course toward high-altitude reconnaissance. Eisenhower also determined that the Central Intelligence Agency, rather than the squabbling branches of the military, should take the lead role.

Taubman is at his best when describing the challenges facing aviation engineers, camera designers, and the pilots who initially were asked to fly arduous long-distance flights at altitudes over 70,000 feet. A U-2 pilot, for example, could fly for eight hours at a time in conditions akin to those atop Mt. Everest and expect to lose six pounds attempting to hold the lightweight spyplane at its safe cruising speed—between 446 and 453 mph. Later, pilots were trained to snag parachute-slowed capsules containing high-resolution cameras and instruments as they descended from orbit. The WS-117L experienced a dozen disastrous launches before it finally worked right, though all the while the Soviets were launching ever more audacious space missions.
—Nan Chase last reviewed Survival City: Adventures Among the Ruins of Atomic America *for* Air & Space.

Celestial Delights: The Best Astronomical Events Through 2010

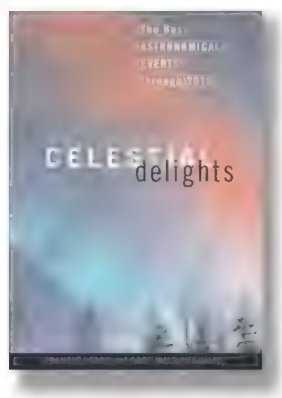
by Francis Reddy and Greg Walz-Chojnacki. Ten Speed Press, 2003. 249 pp., $19.95.

If you get turned around in planetariums or wish that someone could explain the night sky clearly—slowly—here's your book. Part star chart, part calendar, and neither narrative nor reference, *Celestial Delights* is a fine primer for those craving a scout leader's familiarity with the heavens.

The authors elucidate the mechanics of eclipses, retrograde planetary motion, comet flybys, moon phases, and other events plainly and accessibly and always include tangential trivia that can be used to impress friends—a device that occasionally leads to longwindedness.

The most charming details by far are star myths from ancient tribes and civilizations. Perhaps the most delightful tells the tale of a vengeful Chinese sun god who places a heavenly river between his daughter Chih-nu (the star Vega) and her mortal lover Ch'ien-niu (Altaire), only to see them reunite on a bridge of magpies. Indeed, Reddy and Walz-Chojnacki take particular pleasure in pointing out historical implications of astronomy, even extrapolating circumstances and dates during which Biblical events may have occurred.

Unfortunately, the book is undermined by maddeningly uneven illustration—an unforgivable sin for such a visual subject. While charts are well thought out and clear, color plates are wasted on trite close-ups of planets, indecipherable star fields, and *two* time-lapse photos of the moon over Tulsa. Meanwhile, more spectacular shots of comets and coronal mass ejections are printed with all the clarity of a second-generation photocopy.

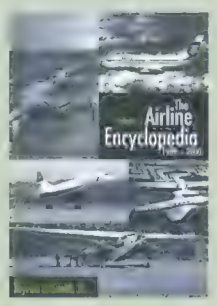


Celestial Delights is alternately fascinating, dry, well written, and repetitive; it's best digested with short bursts of heightened concentration and a caffeinated beverage—try it with a hot cocoa before May 16's lunar eclipse.
—Sam Goldberg is an associate editor at Air & Space.

REFERENCE

The Airline Encyclopedia 1909-2000

by Myron J. Smith Jr. Scarecrow Press, 2002. 3,376 pp. (three volumes), $695.00.



This heavyweight and pricey set is virtually worth its weight in gold. Profiles include all airlines, charter, cargo, firefighter units, offshore helicopter companies, and airship operators. Also provided are company histories, accident/incident statistics, routes, and financial info. The author has compiled 6,556 entries, which prices out to a shade over 10 cents per record.

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26	9.63	9.10	10.50	9.41	15.75	13.56	26.25	21.88
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38	10.33	9.63	11.59	10.72	17.94	16.19	30.63	25.38
39	10.59	9.89	12.25	11.16	19.25	17.06	32.38	27.13
40	10.85	9.98	12.69	11.38	20.13	17.50	35.00	28.88
41	11.20	10.41	13.78	12.47	22.31	19.69	38.50	30.63
42	11.81	10.85	15.09	13.56	24.94	21.88	42.88	35.88
43	12.34	11.38	16.41	14.66	27.56	24.06	48.13	39.38
44	12.86	11.64	17.50	15.31	29.75	25.38	52.50	42.88
45	13.56	11.99	19.25	16.41	33.25	27.56	59.50	48.13
46	14.09	12.34	20.56	17.28	35.88	29.31	64.75	50.75
47	14.88	12.78	22.53	18.38	39.81	31.50	71.75	55.13
48	15.66	13.30	24.28	19.47	43.31	33.69	77.88	59.50
49	16.63	13.74	26.69	20.56	48.13	35.88	85.75	64.75
50	17.33	14.35	28.44	21.88	51.63	38.50	94.50	70.00
51	18.29	14.96	30.63	23.19	56.00	41.13	103.25	75.25
52	19.25	15.75	33.25	25.38	61.25	45.50	116.38	83.13

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	Male	Female	Male	Female	Male	Female	Male	Female
53	20.74	16.63	36.75	27.34	68.25	49.44	128.63	89.25
54	22.14	17.41	40.03	29.31	74.81	53.38	140.88	98.00
55	23.80	18.46	44.19	31.72	83.13	58.19	156.63	107.63
56	25.99	19.43	48.13	33.91	91.00	62.56	171.50	114.63
57	28.35	20.74	53.59	36.97	101.94	68.69	192.50	125.13
58	30.98	22.05	59.06	40.03	112.88	74.81	213.50	135.63
59	33.60	23.28	64.53	43.09	123.81	80.94	234.50	146.13
60	36.84	24.94	71.09	47.03	136.94	88.81	259.88	158.38
61	38.33	26.51	78.09	50.75	150.94	96.25	287.00	174.13
62	42.18	28.61	86.84	55.78	168.44	106.31	322.88	194.25
63	46.46	30.63	95.81	60.59	186.38	115.94	357.88	215.25
64	51.98	33.08	105.00	66.50	204.75	127.75	393.75	235.38
65	57.31	35.26	116.16	71.53	227.06	137.81	437.50	261.63
66	63.18	37.63	128.41	77.22	251.56	149.19	469.88	280.88
67	70.79	40.16	144.59	84.44	283.94	163.63	514.50	307.13
68	78.75	44.28	161.00	92.09	316.75	178.94	559.13	333.38
69	87.33	47.60	177.41	99.75	349.56	194.25	602.88	359.63
70	96.43	51.80	197.97	109.16	390.69	213.06	658.88	392.88
71	108.50	60.90	225.75	131.03	446.25	256.81	869.75	490.00
72	124.43	73.06	262.50	160.56	519.75	315.88	1017.63	604.63
73	140.53	85.31	299.69	190.09	594.13	374.94	1166.38	718.38
74	156.63	97.56	336.88	219.63	668.50	434.00	1315.13	832.13
75	176.75	112.79	383.25	256.38	761.25	507.50	1501.50	974.75
76	199.94	129.50	436.84	296.84	868.44	588.44	1713.25	1131.38
77	233.10	151.90	513.41	350.88	1021.56	696.50	2016.88	1340.50
78	267.05	174.30	591.72	404.91	1178.19	804.56	2326.63	1564.50
79	301.70	196.70	671.56	459.16	1337.88	913.06	2642.50	1794.63
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CREDITS

Launch Count: 15,000 Drones, One Babe. Los Angeles-based freelance writer Stephen Joiner writes about the historical connections between aviation and Hollywood.

Exit Strategy. A retired Air Force colonel, Marshall Michel is a freqent contributor to *Air & Space/Smithsonian*. He is the author of *Clashes: Air Combat Over North Vietnam 1965–1972*. Currently pursuing a doctorate at Auburn University in Alabama, Michel is also writing a book about the U.S.-Soviet air battles during the Korean War.

How to Do Oshkosh. Mark Huber operates an aviation marketing company. His last article for *Air & Space*, "A Price Too High," about the impact of September 11 on general aviation airports near Washington, D.C., ran in the June/July 2002 issue. He plans on flying into and camping at Oshkosh this summer.

Silver Bullet. Preston Lerner has written for *Air & Space* about subjects ranging from old bombers such as the Boeing B-52 to experimental aircraft such as the X-38.

California Dreamin'. George J. Marrett was a test pilot at Hughes Aircraft Company for 20 years. Now retired, he is the author of *Cheating Death: Combat Air Rescues in Vietnam and Laos*, which was recently published by Smithsonian Institution Press.

Backgrounder: What's a Scud? Bruce Berkowitz is a research fellow at the Hoover Institution, an organization that studies U.S. domestic policy and international affairs, and a senior analyst at RAND. His book, *The New Face of War*, was published by the Free Press in March.

Bill Borucki's Planet Search. Andrew Lawler is the Boston correspondent for *Science* magazine.

How the 747 Got Its Hump (And Other Stories). An author of nearly 30 books, including *Lockheed Stealth* (MBI Publishing, 2001), Bill Sweetman writes about aerospace technology and policy. He is based in Minneapolis-St. Paul, Minnesota.

The Pentagon's Flying Saucer Problem. A graduate of the U.S. Naval Test Pilot School, Graham Chandler is now a freelance writer in Calgary, Alberta, Canada. He wrote "Ready, Set, Flap" for the Dec. 2001/Jan. 2002 issue.

CALENDAR

March 10–April 27
Exhibit of Amelia Earhart memorabilia: 500 items, including love letters, fan mail, flight logs, and flying apparel. Purdue University, West Lafayette, IN, (765) 494-2096.

April 5
"Air War Over Vietnam," a seminar featuring veterans of aerial combat over Vietnam. Planes of Fame Museum, World War II CAL-AERO Field, Chino, CA, (909) 597-3722.

April 16–18
Reunion: Jimmy Doolittle Tokyo Raiders of World War II; open to the general public. Travis Air Force Base, CA, (707) 424-5598.

April 25 & 26
Conference: "From Autogiro to Gyroplane: The Past, Present, and Future of an Aviation Industry." The Hofstra Museum is also putting on an autogiro exhibit, which runs from April 1 to August 22. Hofstra University, Hempstead, NY, (516) 463-6817.

April 28–May 2
Space Congress: "Linking the Past to the Future, A Celebration of Space." Cape Canaveral, FL, (321) 724-1688, *www.spacecongress.org.*

May 3
Seminar on the history of Russian aircraft. Planes of Fame Museum, World War II CAL-AERO Field, Chino, CA, (909) 597-3722.

May 3 & 4
McDonald's Air & Sea Show. Featuring U.S. Air Force Thunderbirds and Canadian Snowbirds. Fort Lauderdale, FL, (954) 527-5600, ext. 4.

May 7–11
Red Star Pilots Fly-In, a gathering for owners of Soviet piston engine and jet aircraft. Castle Airport, CA, (310) 386-9181.

May 9–12
Reunion: Air Transport Command Hump Pilots. Crowne Plaza Hotel, Dayton, OH, (315) 938-5327.

May 24
Canada Aviation Museum Fly-In Breakfast. Rockcliffe Airport, Ottawa, Ontario, Canada, (613) 991-6064.

May 24
"To Honor Those Who Served: A Remembrance of War" seminar. Commemorative Air Force, American Airpower Museum, Midland, TX, (915) 567-3009.

Organizations wishing to have events published in Calendar should fax press releases two months in advance to (202) 275-1886 or mail them to Calendar, Air & Space/Smithsonian, *MRC 951, P.O. Box 37012, Washington, DC 20013-7012.*

In the Wings...

The Champ

How a fighter-bomber that served with the Royal Australian Navy in World War II rose from a bunch of parts in crates to win the Rolls-Royce Aviation Heritage Trophy.

CHARLES BROWN COLLECTION/RAF MUSEUM

A Fairey Firefly at parade rest, the posture it assumed on carrier decks.

Thunderscreech

Pity the ears of those who toiled at Edwards Air Force Base when the XF-84H ran up its engine.

NASA Goes Nuclear

To the moons of Jupiter, with ion engines.

Extreme Simulators

Wouldn't you like to have the reconstituted forward fuselage of an F-15 to stick your simulator in? How 'bout a 737 nose section? Or a 70-percent-scale 747-400 cockpit resting on a Ford chassis?

To Snatch a Sabre

For three hours, Russian pilots in MiG-15s fought off F-86 Sabres trying to keep a downed F-86 from falling into enemy hands. But the fighter had gone down on the coast of the Yellow Sea, and time and tide were with the Russians.

ON THE WEB SITE

www.airspacemag.com

Check out the Web site for companies selling models of the Hughes H-1 and download a Microsoft Flight Simulator plug-in that will put you in the cockpit without the million bucks you'd need to build your own replica. Coming soon: the H-1's schedule of airshow appearances. And speaking of airshows, get inspired by a gallery of photos from Oshkosh as you plan your visit to the Experimental Aircraft Association's AirVenture 2003.

LIBRARY OF CONGRESS

"A Hilarious Mood"

Last issue's excerpts from *The Papers of Wilbur and Orville Wright, Volume One, 1899–1905* (McGraw-Hill, 2001), recounted the brothers' completion of their 1902 glider. These excerpts describe them working with the glider at Kill Devil Hill, and succeeding with the vertical tail and the rudder.

Wilbur Wright to George A. Spratt [a fellow believer in manned flight], Kill Devil Hills, September 16, 1902
It would be a pity to have your ideas of camp life here based on your experience of one year ago. First, we have not seen a dozen mosquitoes in the two weeks and a half we have been here. Second, we fitted up our living arrangements much more comfortably than last year. Our kitchen is immensely improved, and then we have made beds on the second floor and now sleep aloft. It is an improvement over cots. Our new well goes down about ten feet deeper than last year, and we now have good water. We also have a bicycle which runs much better over the sand than we hoped, so that it only takes about an hour to make the round trip to Kitty Hawk instead of three hours as before. We are having a splendid time. The main thing though is the new machine. We had it out making some tests of its efficiency today and are very much pleased with the results. If you are really intending to build a large machine you ought to see the three machines at Kitty Hawk this year.

Orville Wright's Diary B, September 19, 1902
Completed the rear vertical tail at 10:30. After dinner took machine to small hill, and after taking two pictures, flying it as kite, began gliding. We are convinced that the trouble with the 1901 machine is overcome by the vertical tail.

Wilbur Wright to Octave Chanute, September 23, 1902
We finished the day with a slight catastrophe which will delay further experiment for two or three days. My brother after too brief practice with the use of the front rudder tried to add the use of the wing-twisting arrangement also, with the result that, while he was correcting a slight rise in one wing, he completely forgot to attend to the front rudder, and the machine reared up and rose some 25 feet and sidled off and struck the ground on one wing tip. We hope to have repairs made in a few days.

Orville Wright's Diary B, September 23
The result was a heap of flying machine, cloth, and sticks, with me in the center without a bruise or a scratch. In spite of this sad catastrophe we are in a hilarious mood as a result of the encouraging performance of the machine both in control and in angles of flight. We have come to the conclusion, that the cause of the sudden rise of the front of the machine is a result of the wind striking on the underside of the front rudder when the relative wind is from one side.

A few mosquitoes tonight.

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LOGBOOK

Events

The National Aeronautic Association 2003 **Spring Awards Reception and Ceremony** will be held on the evening of Monday, March 31, 2003, at the College Park Aviation Museum in College Park, Maryland. This event will celebrate NAA members who have established or broken records, Fédération Aéronautique Internationale award winners, and the winners of the 2003 Young Artists Contest, which is titled "100 Years of Powered Flight." Attendees can mingle with the evening's honorees and other aviation enthusiasts while enjoying the historic exhibits of the museum, which is located at the world's oldest continuously operated airport. For more information, visit NAA's Web site at *www.naa-usa.org* or call (703) 527-0226.

Nominations

The Elder Statesman of Aviation Award is awarded annually to honor outstanding Americans, who, by their efforts over the years, have made significant contributions to aeronautics and have reflected credit upon the nation and themselves. Candidates must be a U.S. citizen and at least 60 years old. Nominations will be accepted from April 1 through June 30, 2003.

The Wright Brothers Memorial Trophy is awarded annually "to a living individual for significant public service of enduring value, as a civilian, to aviation in the Untied States." Nominations will be accepted from April 1 through June 30, 2003.

The Harmon Aeronaut (Ballooning) Trophy is awarded annually for the most outstanding international achievement in the art and/or science of ballooning for the period of July 1, 2002, to June 30, 2003. Nominations will be accepted from April 15 through July 15, 2003.